LJ-75-68

PROGRESS OF RESEARCH ON PORPOISE MORTALITY INCIDENTAL TO TUNA PURSE-SEINE FISHING FOR FISCAL YEAR 1975

by

STAFF, PORPOISE/TUNA INTERACTION PROGRAM
OCEANIC FISHERIES RESOURCES DIVISION

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, California 92038

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INTRODUCTION[1/]

Observations on the problem of incidental mortality of porpoise have been made by NMFS scientists since 1962. In 1970 funding was obtained to actively study the problem.

As a direct result of the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361, 86 Stat. 1027, 1972), the Southwest Fisheries Center (SWFC) of the National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) in the United States Department of Commerce (DOC) increased its research program substantially 1) to develop fishing methods and gear technology which would reduce the incidental mortality of porpoises in the yellowfin-tuna purse-seine fishery and 2) to determine the status of the porpoise stocks associated with the incidental mortality. Results of the SWFC research program have been documented in numerous publications and administrative internal reports, and have been summarized in the following published documents, (1) "Report of the NOAA Tuna-Porpoise Review Committee," issued Septem-- ber 8, 1972, (NOAA, 1972), (2) "Report to the Congress on the Research and Development Program to Reduce the Incidental Take of Marine Mammals, October 21, 1972 through October 20, 1974," issued October 21, 1974, (DOC, 1974), (3) "Report of the Secretary of Commerce on Administration of the Marine Mammal Protection Act of 1972, May 1, 1974 to March 31, 1975," issued June 27, 1975, (DOC, 1975).

[1/] The present report was written by Dr. William W. Fox, Jr. (Chief, Oceanic Fisheries Resources Division) and Dr. William Lenarz (Leader, Porpoise/Tuna Interaction Program), with the assistance of other members of the Program: Dr. David Au, Dr. Eric Barham, Mr. Richard L. McNeely, Dr. William F. Perrin, and Dr. Tim D. Smith.

The present report[2/] provides the results to date of progress on the SWFC's Porpoise/Tuna Interaction Program and will be utilized as background information at hearings some time in late September or early October 1975, on consideration of the issuance of a general permit allowing the tuna industry a continued incidental take of marine mammals. This report will also serve to summarize the research program for Fiscal Year 1975 (July 1, 1974 through June 30, 1975). The present report covers:

(1) a brief review of the porpoise/tuna problem,

(2) an overview of the SWFC research program,

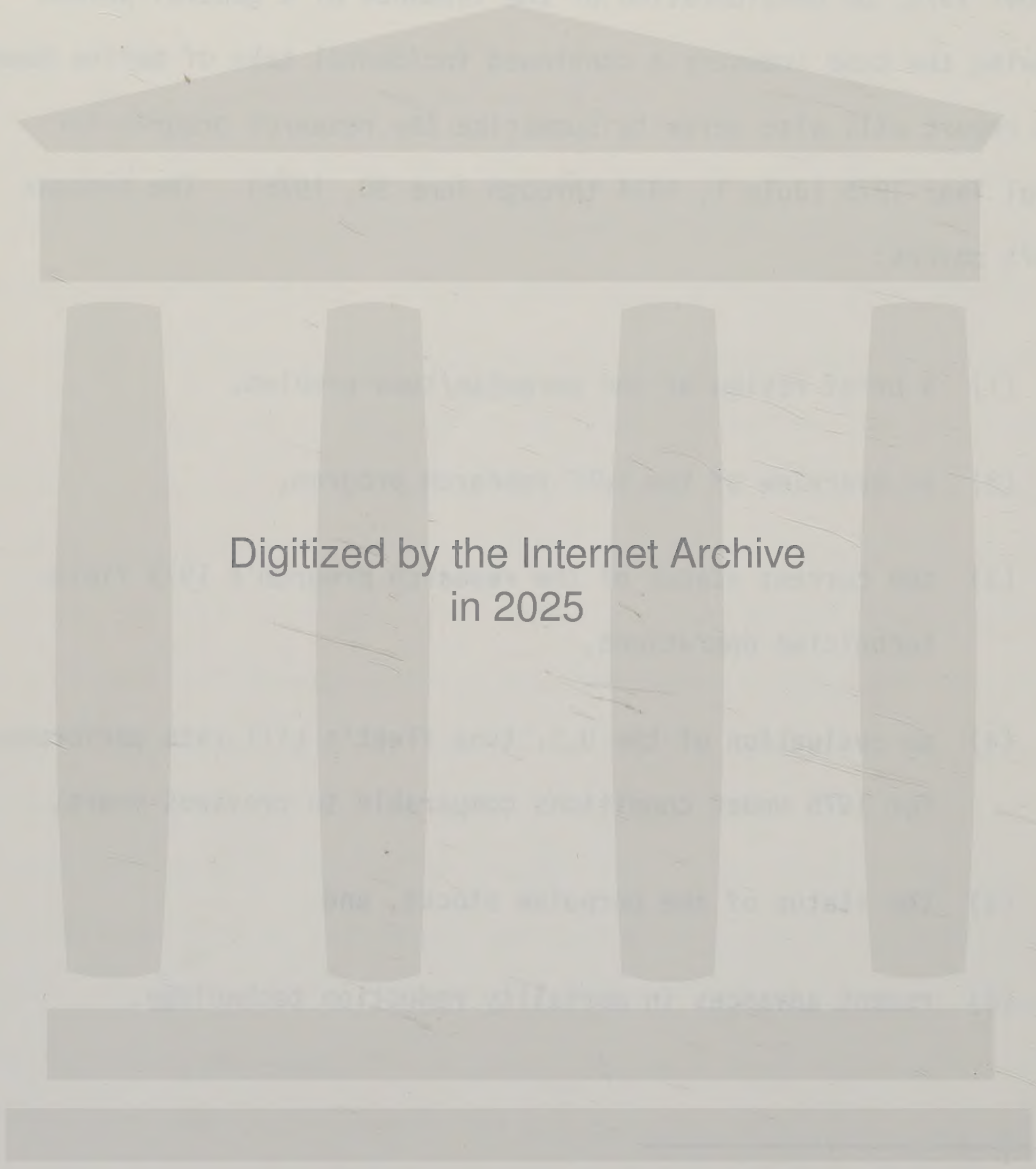
(3) the current status of the research program's 1975 field-technician operations,

(4) an evaluation of the U.S. tuna fleet's kill rate performance for 1975 under conditions comparable to previous years,

(5) the status of the porpoise stocks, and

(6) recent advances in mortality reduction technology.

[2/] This report was compiled in part from detailed technical documents prepared by several scientists of the research program. The detailed technical documents are referenced at appropriate locations in this report and are available from the Director of the Southwest Fisheires Center upon request.



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1.1 Review of the Problem

Incidental mortality of porpoise associated with yellowfin tuna being caused by purse-seine fishing in the eastern Pacific began in the late 1950's when the U.S. tuna fleet converted from primarily fishing with live bait to utilizing a purse seine net in fishing for tuna. Knowledge of the porpoise and yellowfin tuna association acquired through many years of experience in baitboat fishing was utilized, along with the development of methods to herd and encircle porpoise with the purse seine, to evolve a more efficient means to capture tuna. These developments established the U.S. tuna fleet's world prominence. The incidental mortality of porpoise has been extensively documented (NOAA, 1972; DOC, 1974). Estimates of the catch of yellowfin tuna in association with porpoise for the years 1971-1974 are shown in Table 1. Between one-half and one-third of all U.S. domestic tuna landings (all species and all ocean areas) are taken in association with porpoise. The importance of the Eastern Pacific Ocean, yellowfin tuna, and purse seine gear to the U.S. tuna fleet is also apparent in Table 1.

At first the incidental porpoise mortality problem was almost entirely restricted to U.S. vessels. However, other countries fishing for tuna in the eastern Pacific sought to capture larger shares of the limited yellowfin tuna resource and they have in turn developed their capabilities to purse seine yellowfin tuna in association with porpoise (Table 1). Foreign involvement in catching yellowfin tuna associated with porpoise increased markedly from an estimated 2 percent in 1971 to

over 12 percent in 1973 and 1974. Countries besides the U.S. fishing the Eastern Pacific in 1974 were Bermuda, Canada, Costa Rica, Ecuador, France, Japan, Mexico, Netherlands, Panama, Peru, and Spain (IATTC, 1975). There are also indications that the purse-seine fleets being built for Cuba and Senegal will participate in the Eastern Pacific tuna fishery. There are a number of reasons to expect that the foreign involvement in catching yellowfin tuna in association with porpoise will continue to increase at a substantial rate. Several countries expanding in the tuna fishery apparently have governmental policies to do so and have obtained relatively inexpensive capital from international sources. Furthermore, the Inter-American Tropical Tuna Commission (IATTC) regulations and allocation system, and the relatively more effective U.S. enforcement measures, have interacted to make proficient U.S. fishermen, U.S. capital, and former U.S. vessels available to augment and improve the foreign capability. We point out these factors, not to divert attention from the incidental mortality by U.S. fishermen which is still the most significant component, but to emphasize the mounting and often under-appreciated problem of the U.S. losing effective controls over reduction of the total incidental porpoise mortality.

In addition to the expansion of foreign fishing associated with porpoise, which would place a greater proportion of the total mortality outside direct U.S. controls, there are many factors which also act to impede reduction of the total incidental porpoise mortality as well as factors that promote such reduction. The factors that impede the reduction of incidental porpoise mortality are:

(1) When fishing for yellowfin tuna is ceased each year through closing of the Inter-American Tropical Tuna Commission Yellowfin Regulatory Area (CYRA)--Figure 1--to unregulated yellowfin tuna fishing, U.S. purse-seine fishing for tuna not associated with porpoise is largely precluded. This is because tunas not associated with porpoise are seldom vulnerable to purse-seine fishing outside of the CYRA in the eastern Pacific.

(2) Increased use of extended seaward jurisdiction by Central and South American countries will make it more difficult for the U.S. baitboat fleet to obtain adequate bait resources, hence preclude the possibility of increased U.S. baitboat fishing, and further impede U.S. purse-seine fishing for tuna not associated with porpoise.

(3) There is apparently an increase in the overall productivity of the yellowfin tuna fishery when fishing in association with porpoise. The estimated maximum sustainable yield increased sharply as the tuna fishery expanded offshore in the mid-1960's primarily through catching yellowfin tuna associated with porpoise (IATTC, 1975).

Conversely, there are two types of factors that promote the reduction of incidental porpoise mortality. One type is the result of widespread public concern over porpoise mortality as manifested in the statutes--there is clear legal requirement that porpoise mortality be reduced.

The other type of factor arises from a concern with the efficiency of the fishing operation itself:

(1) It is time-consuming for extensive porpoise mortality to occur in a set of the purse seine;

(2) The safety of the crew is jeopardized by handing porpoise from skiffs, on the deck of the seiner, and in the water;

(3) Since the presence of porpoise schools remains a primary means of locating yellowfin tuna, reductions in porpoise populations will eventually lead to decreased fishing efficiency.

These latter are significant incentives, when recognized, for foreign fishermen, as well as U.S. fishermen, to reduce the incidental mortality of porpoise. These incentives actually place a value on the porpoise to the fishermen.

The value of porpoise to the fishermen stimulated actions by the U.S. fishermen to attempt to solve the problem of incidental mortality prior to governmental intervention. The U.S. fishermen's actions have involved development of the backing-down procedure for releasing encircled porpoise, developing the porpoise safety panel (Medina panel) to retard entanglement, and using fishermen around the perimeter of the purse seine to manually remove animals. Government analyses supported the efficacy of these developments. Additional measures, procedures, and equipment were instituted in a series of regulations for the 1973-1975 fishing seasons. Discussions of these developments are contained in NOAA (1972), in DOC (1974), and in subsequent sections of this report.

Research efforts by foreign governments have been limited as far as we are able to determine. In 1974 Canada placed field technicians aboard several of their vessels to record data on incidental porpoise mortality. Efforts by international organizations on the porpoise mortality problem, however, are increasing. In March 1975, the member countries of IATTC voted in favor of a special allocation of 1,000 short tons of yellowfin tuna from the CYRA quota for use by the U.S. research program during 1975. In practice, however, the allocation is subtracted from the open season portion of the quota which is taken primarily by U.S. fishermen, i.e., most of it came from the U.S. fishermen. The Food and Agricultural Organization of the United Nations (FAO) has established a committee on small cetaceans which has recommended an international research program. The Scientific Committee of the International Whaling Commission has established a standing committee on small cetaceans to collect and analyze data on the status of porpoise stocks and has recommended that member nations be required to report incidental kills of cetaceans in tuna purse-seiner operations (as well as other fishing operations).

1.2 Overview of the Research and Development Program of the Southwest Fisheries Center

The SWFC Porpoise/Tuna Interaction Program has two basic objectives:

(1) Develop methods, techniques, and technology to reduce porpoise mortality incidental to yellowfin tuna purse seine fishing.

(2) Determine the status of the porpoise stocks.

The program consists of three somewhat related components: a) mortality reduction technology, b) general biology, ecology, and population dynamics, and c) data management and quantitative analysis. These components will be briefly reviewed below and the results will be discussed at length in subsequent sections of the report.

1.2.1 Administration

The Porpoise/Tuna Interaction Program is now one of two programs in the Oceanic Fisheries Resources Division of the SWFC; as of the end of the 1975 Fiscal Year (July 1, 1974 through June 30, 1975) it included eleven permanent technical employees (seven senior research scientists and four junior scientists and technicians), and six temporary employees (data processing technicians). Two of the senior scientific employees also have duties in other programs of the SWFC. Through reorganization at the SWFC and adding personnel, there has been an increase of three permanent senior scientific employees over Fiscal Year 1974. The increase occurred for the most part near the end of Fiscal Year 1975. Funding of the program, base funding (about $400,000) plus one-time expenditures (about $190,000), totaled approximately $590,000 for Fiscal Year 1975 compared with a combined total of $930,700 for Fiscal Years 1973 and 1974. Base funding for Fiscal Year 1976 is $403,000, approximately the same as for Fiscal Year 1975. Major one-time expenditures above base during Fiscal Year 1975 were for increased numbers of trips for field technicians, the establishment of a data management system, and the purchase of gear technology supplies.

1.2.2 Mortality reduction research and development

Mortality reduction research and development concentrated on what was termed "Phase One" activities by the Porpoise Committee (NOAA, 1972), that is, improvement, modifications, and supplements to existing purse-seine fishing technology. The research concentrated on mechanisms for reducing mortality if and when porpoise contact the net, and reducing the probability of contact, through minor changes in gear and procedures, as opposed to more sophisticated electronic, chemical, or biological mechanisms which might prevent contact with the net, "Phase Two" activities. As stated in our previous report (DOC, 1974) our research priorities are based on the resources available and the probability of success in the short term. We hope to execute longer term sophisticated projects of the "Phase Two" type with base funding in Fiscal Year 1976.

This task concentrated on six projects during Fiscal Year 1975, which are:

(1) the porpoise apron,

(2) finer mesh webbing,

(3) the large volume purse seine,

(4) anti-torque purse cable,

(5) lengthened current ribbons, and

(6) the porpoise grabber (a handling device to aid manual removal of porpoises).

These projects are aimed at alleviating previously identified major sources of mortality such as net collapse, creation of canopies, individual entanglement, and "sacking up" operations (DOC, 1974), which will be discussed in some detail in subsequent sections of this report.

During Fiscal Year 1975 we conducted two gear research cruises. In addition, the large volume purse seine, the porpoise apron, anti-torque purse cable, lengthened current ribbons, and porpoise grabber received additional testing in the U.S. purse-seine fleet with the cooperation, participation and investment of members of the U.S. purse-seine fleet. Descriptions and discussions of these tests are given in subsequent sections of this report, but much of the results are as yet unavailable since many of the vessels are still at sea.

1.2.3 Biological research

A major paper on the general biology of the offshore spotted dolphin (*Stenella attenuata*), historically the species with the highest mortality, was revised and completed during Fiscal Year 1975 (Perrin, Coe, and Zweifel, MS) and the results are incorporated in our section on Status of Stocks. Our biological research has since concentrated on the biology of the eastern spinner dolphin (*Stenella longirostris* subspecies), the species with the second highest total incidental mortality, and some preliminary results (Perrin, Holts and Miller, 1975) are utilized in our Status of Stocks section. Our work on the biology of the common dolphin *(Delphinus* species), the species with the third highest mortality,

and the striped dolphin (*Stenella coeruleoalba*), a more rarely encountered species, is continuing with increased effort due to completion of the spotted dolphin work and good progress on the spinner dolphin biology. One of our difficult problems, direct calibration of age, is receiving special attention through a contract with Dr. Jeffrey Bada of the University of California at San Diego. Dr. Bada is applying his new technique of aging mammals through biochemical analysis of dental protein.

Our population dynamics research has concentrated on:

(1) estimation of incidental mortality (this report),

(2) a revision of preliminary population estimates from aerial and shipboard surveys (Smith, 1975), and

(3) the status of the Eastern Pacific porpoise stocks (this report).

An appreciable amount of our quantitative resources were allocated to evaluate the U.S. fleet kill-rate performance under conditions comparable to previous years during the early 1975 fishing season (this report). In Fiscal Year 1976, we intend, with base funding, to concentrate on:

(1) studying the detailed purse-seine fishing process to standardize searching effort in order to develop indices of porpoise abundance,

(2) the population dynamics of the spotted dolphin and, in particular, the spinner dolphin, and

(3) a detailed quantitative analysis of porpoise behavior.

PRELIMINARY EVALUATION OF THE U.S. FLEET KILL RATE FOR CALENDAR YEAR 1975

There are many criteria which can be used to judge the performance of the U.S. purse-seine fleet in reducing the incidental mortality of porpoises. An obvious criterion is total annual kill, which is of paramount importance in evaluating the impact of the incidental mortality on the status of the porpoise stocks. However, the total annual kill can be broken down into two kinds of components, the kill rate (kill per set, kill per ton of yellowfin captured, kill per trip, etc.) and the total number of operations (number of porpoise sets, total tons of yellowfin caught in association with porpoises, total number of trips, etc.). Current gear technology efforts and regulations have been designed to reduce the kill rate, hence in this section we analyze the kill rate of the U.S. fleet. The estimated total annual mortality of porpoises is examined under Status of Stocks (Section 3).

2.1 Current Status of the 1975 Field-Technician Operations

The field-technician operations (commonly referred to as the "observer program") began in 1966 but have been conducted continuously only since 1971 when direct funding became available. Each year there was an increase in the number of U.S. tuna seiners cooperatively carrying field technicians to collect mortality data--1 in 1968, 6 in 1971, 13 in 1972, 24 in 1973, and 41 in 1974. Prior to 1974, the tuna seiner trips were taken on an opportunity basis. In 1974, vessels were selected on

a random basis stratified by four vessel-characteristic categories. Good cooperation from most of those selected resulted in coming close to the stratified random selection plan. The field technicians have at least 2 years of college education in biology and receive an intensive 2-week course on procedures used to collect the data at sea. Many of the observers have a college degree and many have been on more than one trip. This section presents certain improvements in the data base collected by field technicians and a chronology of events for the field-technician trips of the 1975 fishing season.

2.1.1 Improvements to the 1975 data base

There were several improvements to the 1975 data base:

(1) The format of the 1975 field-technician data forms were altered to facilitate recording and keypunching.

(2) Increased detail in position and activity records were collected to better define search area for estimating porpoise densities and to better define fishing effort for developing indices of porpoise abundance.

(3) The use of cameras for identification of specimens was re-instituted, after being dropped for 1974.

(4) More detail was included on the causes and conditions of the incidental mortality.

(5) Variables for classifying sets were added to evaluate the effectiveness of 1975 regulations in reducing incidental mortality.

(6) In response to many criticisms of our previous mortality estimates, the field technicians were trained to recognize injured porpoise that are released alive and provisions were made to record these estimates as well as those of animals immediately killed.

2.1.2 Chronology of events during 1975

In December 1974 it was determined, through analyzing the variability of kill per set among trips for previous years, that significant reductions in variability could not be obtained without greatly increasing the number of trips beyond 36. On the other hand, if the number of trips were reduced below 36, variability would increase. Therefore, for 1975, the original plan called for a total of 36 trips to be selected on a random basis from three vessel-category strata (class I = vessels <401 tons carrying capacity, class II = vessels >400 tons built before 1961, and class III = vessels >400 tons built during or after 1961) with 24 allocated to trips within the CYRA and 12 to trips which occur to the west of the CYRA. Prior to 1975, the program was unable to obtain a significant number of samples from regulated trips to the west of the CYRA. Given present resources, the 36 trips for the 1975 fishing season were distributed among strata of trip type and vessel class as follows:

Vessel class	Number of Trips within CYRA		Number of trips outside CYRA
	Planned	Obtained	Planned*
I (<401 tons)	3	3	0
II (>400 tons, <1961)	3	1	3
III (>400 tons, >1960)	18	18	9
TOTALS	24	22	12

*Attempts were being made at the time of writing to place field technicians aboard outside trips.

The distribution among strata was based on the historic yellowfin catch associated with porpoise.

A drawing was held to order all U.S. purse seiners randomly. A total of 36 were assigned to the six strata. Twenty-two trips were obtained on U.S. purse seiners which left for the 1975 fishing season during the first 2 weeks of January 1975. One additional trip (not shown in preceding table) was obtained which left at a later date because the vessel had been fishing in the Atlantic Ocean. In order to obtain the number of planned CYRA trips for each of the vessel classes, some vessels that were not part of the original 36 and some vessels selected for outside trips had to be used on CYRA trips. Generally good cooperation was obtained from all but a few purse-seine vessel owners and skippers. Placing field technicians on class II vessels proved to be most difficult.

During hearings on proposed 1975 regulations held December 10-11, 1974 in Washington, D.C., Dr. James Joseph, Director of Investigations of the IATTC, testified that the logbook required by NMFS on all vessels fishing porpoise might affect the IATTC data base. Since our previous

method of estimating total porpoise mortality depended heavily on the IATTC data base, it was decided in late February 1975 to ensure that a reliable estimate could be made by using only the field technician data of kill of porpoise per trip and the total recorded number of vessel trips. It was necessary to increase the number of trips because the number of porpoise sets per trip, hence kill per trip, has historically been much lower during the last unregulated trip, which begins within 30 days after the yellowfin tuna open season closes (about mid-March to June) than during the first trip of the season. The lower kill per trip is usually due to increased availability of skipjack and, for the past 2 years, yellowfin tuna not associated with porpoise. It was determined through examination of the variability of kill per set among trips that 5-10 additional trips would be required to retain the desired precision. Eight trips were obtained, but two were on vessels which had the experimental porpoise apron (see Section 4.2) installed and thus may not be representative of the rest of the tuna purse-seine fleet. The last unregulated trip sample plan and those trips obtained are as follows:

	Last Unregulated Trips	
	Planned	Obtained
Class I	1	1
Class II	2	1
Class III	5	4(+2*)
Totals	8	6(+2*)

*Vessels with porpoise aprons.

Again the program encountered good cooperation from the U.S. purse-fleet withfleet with the exception of class II vessels. An apparently representative sample was obtained, but the planned random order of vessels was not achieved.

In summary, the 1975 field-technician program working cooperatively with the tuna industry obtained 30 trips, which adequately covered the entire U.S. unregulated, yellowfin tuna, fishing season within the CYRA. Temporal coverage of the U.S. fishing operations was better than expected due to unusual economic problems in the U.S. tuna industry and unresolved issues regarding the IATTC yellowfin regulations, which caused many trips to be considerably longer than in previous years.

No trips to the west of the CYRA with field technicians aboard were completed prior to the end of the 1975 Fiscal Year (June 30, 1975). A significant delay occurred in obtaining trips to the west of the CYRA as NMFS began a modification to its research field technician operations--nearly all of these trips will not begin until August. The modification involved collecting more detailed and accurate information on compliance with the NMFS regulations. Therefore, the responsibility for the field operations was transferred to the Southwest Regional Office (NMFS's component for surveillance and enforcement of regulations). While we anticipate that most of the data previously collected by field technicians will continue to be collected, it is not known whether data representative of the entire U.S. fleet will be obtained. The delay encountered through this re-organization will probably not be significant from the standpoint of data coverage, and the data should provide improved information on questions relating to procedures required by regulations.

2.2 Analysis of the U.S. Fleet Kill Rate

Mixed results are produced if one attempts to evaluate the U.S. fleet's progress in reducing the porpoise kill rate with a superficial examination of the summary statistics of the field-technician operations shown in Table 2. The number of porpoise killed per porpoise set (henceforth simply called the kill per set)--increased in 1975 after showing a decline each year since 1971 (Item 10, Table 2); such is also the case for the number of porpoise killed per ton of yellowfin tuna captured per porpoise set (kill per ton; Item 11, Table 2). However, the number of porpoise killed per porpoise set per porpoise caught (kill per porpoise caught), continued to decrease (Item 12, Table 2). The frequency distributions of porpoise killed per porpoise set is fairly similar for 1973, 1974, and 1975 (Table 3, Figure 2).

The primary observation is the kill per set, and each of the other statistics represents a simple attempt to correct for just one variable presumed to affect the kill per set (i.e., kill per ton and tons of yellowfin per set, and kill per porpoise captured and number of porpoise caught per set). School type is another variable that is likely to affect the kill per set. The kill per set for the first 20 field-technician cruises of 1975 is plotted against these variables (Figure 3). Each variable appears to be related to the kill per set and each variable has differed among years (Table 2, Items 2-9), so in order to make a fair comparison between the years, one must examine the kill per set for each year on the same school type (e.g., spotted dolphin only), similar number of porpoise captured, and similar amount of yellowfin tuna captured.

We only used the data from 1973, 1974, and 1975, because of a paucity of data for 1971 and 1972. The first 20 field-technician trips of 1975 were completed by May, so only the data from the same time period in 1973 and 1974 were used. Furthermore, as shown in Table 2, nearly all of the sets were made on either pure schools of spotted dolphin or schools of spotted and spinner dolphins combined, "mixed schools," and the majority of our data was obtained from class III vessels, so we have ignored the small amount of data from other vessel classes and from other porpoise school types in the present analysis.

The set data were examined by school type, number of porpoise captured, and tons of yellowfin caught. Estimates of porpoise captured and yellowfin caught are made by the fishermen. While estimates of catch of yellowfin are considered to be reasonably precise, it is difficult to precisely estimate the numbers of porpoise, particularly when large numbers are involved. However, by dividing the data into only four groups, numbers of porpoise captured between 0-500 or greater than 500 and yellowfin caught between 0-20 tons, or greater than 20 tons, we believe that the statistics are reasonably reliable. We also chose to use only four groups to avoid groups with very small numbers of sets. In addition, early preliminary examination of the kill per set and number of porpoise captured by smaller intervals resulted in a regular relationship of increasing kill per set with increasing number of porpoise and tons of yellowfin captured (Figure 3), hence finer groupings than we chose would not alter the conclusions we reach below.

2.2.1 Comparison of kill per set in sets on pure schools of spotted dolphins

The overall statistics for pure spotted dolphin schools in Table 4 indicate that the kill per set on spotted dolphin declined 23% between 1973 (8.03) and 1974 (6.17) and 26% between 1974 (6.17) and 1975 (4.56). Examination of the kill per set for each year in each group, reveals that 1975 was the lowest in two groups and the second lowest in the other two groups (Figure 4).

Since the kill of porpoise is apparently related to the size of the catch of yellowfin and porpoise in the net, and since the distribution of sets in the four groups differed somewhat among the years (Table 4), we next estimated what the kill per set on pure schools of spotted dolphins would have been in 1973 and in 1974 if the set distribution by groups of catch of yellowfin and number of porpoise during 1975 had occurred in those two years (Figure 5)[3/]. The average kill per set for all sets on pure spotted dolphin schools would have been 7.81 in 1973 if the 1975 distribution of sets had prevailed instead of 8.03 as observed, and in 1974 the kill rate would have been 6.95 instead of 6.17 as observed. Thus, it appears that under similar conditions the kill per set on schools of pure spotted dolphins decreased 11% between 1973 (7.81) and 1974 (6.95) and 34% between 1974 (6.95) and 1975, (4.56) with an apparent overall reduction of 42% between 1973 (7.81) and 1975 (4.56).

[3/] The calculation for 1973, for example, is (155 x 4.64)+(42 x 7.82)+(11 x 14.89)+(21 x 27.43) divided by (155 + 42 + 11 + 21), which is equal to 7.81.

2.2.2 Comparison of kill per set in sets on mixed schools consisting of spotted and spinner dolphins

Data from sets made on mixed schools consisting of spotted and spinner dolphins were also compiled by catch of porpoise and yellowfin, Table 5. The overall kill per set for all sets decreased markedly between 1973 (38.30) and 1974 (20.94) and increased somewhat between 1974 (20.94) and 1975 (23.97). Upon examination of the individual groups of kill per set as in the pure spotter school analysis, however, it is apparent that 1975 was the lowest in all four of the groups (Figure 4).

As in the case of sets made on pure spotted dolphins, kill per set increased when either porpoise captured or yellowfin caught increased and since the distribution of these sets among groups differed between years (Table 5), we again estimated what the kill in sets on mixed schools would have been in 1973 and in 1974 if the distribution of sets observed in each group of porpoise and yellowfin caught during 1975 had occurred in the earlier years (Figure 5). The average kill per set for all sets would have been 43.03 in 1973 if the 1975 distribution of sets had prevailed instead of 38.30 as observed, and in 1974 the kill rate would have been 29.90 instead of 20.94 as observed. Thus, it appears that under similar conditions the kill per set on mixed spotted and spinner dolphins decreased 31% between 1973 (43.03) and 1974 (29.90) and 20% between 1974 (29.90) and 1975 (23.97), with an apparent overall reduction of 44% between 1973 (43.03) and 1975 (23.97).

2.2.3 Comparison of average kill per set for all sets adjusted for school type, school size, and catch of yellowfin tuna

The average kill per set on pure spotted dolphin schools and mixed schools combined show a decline between 1973 and 1974 and an increase between 1974 and 1975 (Table 6) that is in agreement with the summary statistics (Table 2). Table 6 also shows that the fraction of sets on mixed schools decreased from 53% in 1973 to 46% in 1974, but increased to 60% in 1975. Since it was shown that the kill rates for mixed sets are consistently higher than that for pure spotted dolphin schools (Figure 4), a change in school-type composition has an appreciable effect on the average kill per set from all sets (Tables 2 and 6). In order to compare the average kill per set for all porpoise sets by the U.S. fleet in 1973, 1974, and 1975 under comparable conditions, we estimated what the average kill per set would have been in 1973 and 1974 if the distribution of sets observed in 1975 for each type of set, catch of yellowfin, and number of porpoise captured had occurred in earlier years (Figure 5). The results indicate that kill per set would have been 28.78 in 1973 if the 1975 distribution of sets had prevailed instead of 24.05 as observed, and in 1974 the average kill rate would have been 20.61 instead of 12.93 as observed. Therefore, under comparable conditions the overall kill rate apparently decreased 28% between 1973 (28.78) and 1974 (20.61) and 22% between 1974 (20.61) and 1975 (16.12) with an apparent overall decrease of 44% between 1973 (28.78) and 1975 (16.12). The fact that conditions were very different between 1975 and previous years is emphasized by the 60% difference between adjusted (20.61) and observed (12.93) values for 1974.

2.2.4 Possible causes of the apparent decline in kill per set under comparable conditions between 1974 and 1975

While many regulations were promulgated for 1975, the only data sufficient for analysis are for the use of men at the net to manually remove porpoises. In our previous report (DOC, 1974; Table 2) it was shown that, if always used, a net tender in the backdown area could significantly reduce the incidental porpoise mortality, perhaps by as much as 12%. We re-examined the 1974 data and constructed Table 7 to more accurately determine the possible effects of increased use of rescuers at the corkline; only 13 cruises could be examined in this manner. It can be seen that if two or more rescuers were always used then the kill per set might have been reduced in 1974 by as much as 38%.

The 1975 regulations specified and resulted in an increased use of rescuers at the corkline over 1974. During 1975 the field technicians collected more detailed data on the effectiveness of rescue operations than in 1974. The data were sufficient for 12 cruises to estimate the number of live porpoise left in the net after backdown (see Section 4.2) and the number of live porpoises rescued (Table 8)--the percentage rescued for these cruises was 44%. If the utilization rate of rescuers observed in 1975 is applied to the observed relationship between use of rescuers and kill per set for 1974, the average kill per set would have been 8.66 instead of 11.44 as observed (Table 7), an apparent reduction of 24% which is in close proximity to the estimated 22% reduction in kill per set between 1974 and 1975 under comparable conditions (Section 2.2.3).

2.2.5 Summary and conclusions

Based upon the consistency of the comparisons in Tables 4 and 5 and the overall calculations, we believe it reasonable to tentatively conclude that the performance of the U.S. fleet in reducing the kill per set under comparable conditions did improve in 1975, apparently due to increased use of rescuers at the corkline. More rigorous standard statistical analyses, e.g., analysis of covariance, have many assumptions, e.g., normal distribution of the error terms and measurement of the independent variables without error. These assumptions are violated and have, at present, unknown effects on the probability statements about conclusions reached from these tests. This problem can be surmounted, at least in part, through the use of various transformations of the variables and the use of non-parametric statistics. These studies are currently in progress and will incorporate a number of other variables yet to be examined in detail, e.g., successful vs unsuccessful sets (those catching less than 1/4 ton of tuna), time of day, geographic location, and oceanographic or meteorological conditions. Since the kill per set is considerably higher for sets on mixed schools than for sets on pure schools of spotted dolphins, we also plan to examine the factors underlying the marked increase in percentage of sets on mixed schools noted in 1975 and further examine the apparently higher kill per set in mixed schools compared with pure spotted dolphin schools of the same school size (Figure 3).

STATUS OF STOCKS

A primary objective of the Porpoise/Tuna Interaction Program is to determine the status of the porpoise stocks involved in the international tuna fishery of the eastern Pacific Ocean. To date our approach to develop an information base has primarily involved the use of aerial and ship surveys to determine population sizes, the use of field technicians and the IATTC data base to estimate incidental mortality, the use of field technicians to determine species and stock composition and basic biological parameters, and the use of minor tagging efforts to determine migration patterns. Interim understanding of the status of these stocks has been documented in at least three review papers (NOAA, 1972; Royce, 1974; and Perrin, Smith, and Sakagawa, 1974).

Our analytical techniques were reviewed in Perrin, Smith, and Sakagawa (1974). The present report utilized the same basic techniques, but updates a number of the estimates and reports on further examination of several assumptions critical to our previous mortality, population size, and biological parameter estimates.

There are at least seven species of porpoise involved in the international tuna fishery of the Eastern Pacific Ocean (DOC, 1975). Of these seven, three species account for 99 percent of the deaths: spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), and common dolphin (*Delphinus delphis*). Apparently there are two forms of spotted dolphins and three forms of spinner dolphins involved in the

fishery, and they have been described by Perrin (1975). The status of our research on the three major species and their several forms is given in Table 9. As noted in the table, there are critical assumptions in our assessment work that warrant further data collection or study--these are outlined in detail in the following sections of this report. The status of our current knowledge allows detailed examination of only two forms: the offshore spotted dolphin and the eastern spinner dolphin. There is insufficient information to make an assessment of the whitebelly spinner dolphin or the common dolphin stocks, the other two stocks with an annual mortality of more than 1000.

The stock assessment results presented here focus on 1974, where most of the pieces of information come together. With several additional assumptions, one could work within the 1971-1975 period where virtually all our information was derived. Making estimates prior to 1971 is largely speculative at this juncture, as the only real information available is the number of overall sets on porpoise (not by species), the catch of tuna, and fishing effort data from IATTC records. Some work has been done with these data (e.g., NOAA, 1972), but further detailed analyses of "fishing effort" for porpoise is required, which is a project scheduled for Fiscal Year 1976.

3.1 Estimation of Incidental Mortality

Many different methods have been used to estimate the incidental mortality of porpoise, all based on expansion of the mortality

rates by species estimated from data collected by our field-technician operations but each using different assumptions. All of our field technician trips are from U.S. purse-seine vessels and nearly all of them to date have taken place on unregulated trips within the CYRA (Figure 1). Therefore, the mortality rates for non-U.S. vessels and for all vessels during regulated trips, mostly to the west of the CYRA, are unknown.

We continued to use the estimation procedure reported by Perrin, Smith, and Sakagawa (1974), which stratifies the kill per set recorded by field technicians and the porpoise sets recorded in the IATTC logbooks by vessel size class, U.S. vs. non-U.S. sets, unregulated trips within the CYRA vs all other trips, and successful vs unsuccessful sets. The average kill per set estimated by field technicians is assumed to be the same for all non-U.S. strata and U.S. regulated trip strata. The estimate is made by multiplying the kill per set by total porpoise sets within strata and then summing over strata after a correction within each stratum is made for sets not recorded in the IATTC logbook sample.

In addition to the assumptions made for missing kill-per-set strata, other critical assumptions are (1) that all porpoise sets made by vessels included in the IATTC sample are recorded as porpoise sets and (2) that the kill rates, which are for directly observable deaths with some pro-rating of animals of unknown status, are the only deaths which occur. These latter two assumptions are examined in part in the present report.

3.1.1 Incidental mortality estimates, 1971-1974

Estimates of the incidental porpoise mortality in the international yellowfin tuna purse-seine fishery of the eastern Pacific Ocean, 1971-1974, are shown in Table 10. The estimates of total porpoise mortality and those for the two species which account for most of the kill, spotted and spinner dolphins, declined in 1974. The final estimate of total mortality, 113,000 deaths, is lower than the preliminary projected estimate for 1974 (Royce, 1974; Perrin, Smith and Sakagawa, 1974) which was a range of 132,000 to 161,000. The difference is mainly due to a large reduction from the preliminary estimate of the percentage of yellowfin caught on porpoise from early IATTC records. This illustrates how difficult it is to make projections of total mortality for the year. The very low percentage of yellowfin taken on porpoise in 1974 is due to the record high catches of very small yellowfin in the Central American Bight (IATTC, 1975).

3.1.2 Check for possible bias resulting from under-reporting of porpoise sets

The number of trips by U.S. purse-seine vessels that occurred during the 1974 yellowfin tuna unregulated fishing season from the records of the Southwest Regional Office of NMFS are given in Table 11. The trips were stratified by three vessel classes and three trip categories. The unregulated fishing season can be divided into two categories of

trips: (1) open fishing prior to the closure date, when historically a high percentage of porpoise sets are made per trip, and (2) the last unregulated trip which must commence within 30 days after the closure date, when historically a large number of sets are made on tuna not associated with porpoise. About 15 percent of the trips overlapped the closure date, however, and depending in part upon the degree of overlap, their frequency of sets on porpoise is likely to be very different. This is because the closure date in recent years has been in early to mid-March when, historically, yellowfin not associated with porpoise, and also skipjack tuna, have become more available after March.

The sample data obtained by field-technician operations during the same time period in the same vessel-trip strata are also shown in Table 11. Three of the nine strata have no observations and an additional three have only one observation. To make a reliable estimate, it is necessary to combine several strata and estimate the average kill for one vessel-trip stratum (Table 12). The trips for the overlap stratum were pro-rated to the remaining two strata on the basis of the proportion of trips in each of the remaining trip-type strata, and vessel classes II and III were combined. The average kill for Class I late season trips was assumed to be in the same ratio of late to early season as for the combined Class II and III trips. By this method, the estimated total kill of porpoise by U.S. purse seiners during the 1974 unregulated fishing season is 57,324. Collapsing the middle trip stratum in several other possible combinations resulted in estimates of 56,780 to 59,306 porpoise killed.

The comparable porpoise mortality estimate for U.S. vessels fishing in the CYRA from the method used in the previous section, which depends upon accurate records of porpoise sets in the IATTC logbooks, is 63,000. The estimate also includes a minor number of sets made on regulated trips within the CYRA. We conclude that there is no evidence, at least for 1974, of important bias resulting from possible omissions of porpoise sets in the IATTC data base from the CYRA.

3.1.3 Projection of 1975 total porpoise mortality

Our previous estimates of the total porpoise kill for the years 1971-74 were stratified by vessel size class, by U.S. and foreign fleets, by successful and unsuccessful sets, and by inside and to the west of the CYRA, and were based upon the average porpoise killed per porpoise set recorded by field technicians. As noted previously, the total kill estimates were expanded on the basis of the amount of yellowfin caught in association with porpoise for the U.S. fleet fishing to the west of the CYRA and for the foreign fleet in total, because no estimates of the kill per set were available in those strata. At present, we do not have sufficient data to do this type of estimate for 1975, even as a gross projection. However, the average kill per ton of yellowfin tuna captured can be used to make a likely range projection for 1975. These projections, as in the past, are for the observable kill only and are not adjusted for injured animals that may subsequently die or any other direct or indirect deaths.

Regulations for 1975 require each vessel setting on porpoises to provide NMFS with estimates of the total porpoise mortality by species, along with other information, in the form of logsheets. This data was

examined as a possible source for estimating the 1975 incidental porpoise mortality. The mortality estimates, however, were appreciably lower for vessels which did not have NMFS field technicians on board. Therefore we do not consider the NMFS porpoise logsheets to provide reliable estimates of porpoise mortality.

It is necessary to estimate three statistics to project the total eastern Pacific observable porpoise kill for 1975; 1) the average observable kill per ton of yellowfin tuna taken on porpoise, 2) the fraction of the total yellowfin tuna catch taken on porpoise and 3) the total yellowfin tuna catch.

First, we assumed that the average observable kill per ton for the first 20 field technician cruises of 1975 (1.20) will remain within about 10 percent of that value throughout the rest of the year, as it did in 1974, and that it is also representative of the foreign fleets. Based on the previous year's data and the 1975 cumulative plot of kill per ton of yellowfin tuna on total observed sets (Figure 6), this assumption is probably valid for the U.S. fleet in the CYRA. Also shown in Figure 6 is preliminary 1975 estimate of the kill per ton for the first 29 field-technician cruises and a ±10 percent range of the final value for the first 20 cruises. In addition, the overall estimated kills per ton for 1973 and 1974 were about 10 percent less than the average kill per ton from field-technician operations due to the stratification procedure in estimating the total kill. Combining these values produces a projected kill-per-ton range of 0.97-1.19. At present, we have no means of checking the validity of the assumptions about either the U.S. fleet outside the CYRA or the foreign fleets.

Second, we observe that the fraction of total yellowfin tuna catch taken on porpoise has ranged between 0.48 and 0.75 for the years 1974 and 1972, respectively (see table below). This fraction for the first 20 field technician cruises of 1975 is 0.81, but the fraction for the whole year historically has been much less. From Southwest Regional Office records, the fraction of yellowfin that was caught on porpoise for 185 landings of U.S. vessels during 1975 is 0.69, compared with 0.52 for the same period in 1974, and compared with the final international average of 0.48 for 1974 (see table below).

Year	Fraction of yellowfin tuna catch taken on porpoise for year (IATTC records)
1971	0.59
1972	0.75
1973	0.64
1974	0.48

Third, the 1975 yellowfin tuna catch for the CYRA is likely to fall between 170,000 and 190,000 tons, since it is about 7 percent behind that of 1974 for the same time period. The 1975 yellowfin tuna catch outside the CYRA is likely to fall between 30,000 and 50,000 tons, since it is about 8 percent behind 1974 for the same time period. This gives a projected total eastern Pacific catch of yellowfin tuna between 200,000 and 240,000 tons.

Therefore, by combining the projected range in kill per ton, 0.97-1.19, with the observed ranges for the fraction of yellowfin caught on porpoise and the total yellowfin catch, our estimate is that the

1975 total observable porpoise kill for all fleets in the eastern Pacific Ocean will probably fall within the range of 93,000 to 214,000 animals. We emphasize that these are our best estimates of the upper and lower bounds with the data in hand. For example, they may be compared with our revised preliminary kill estimate for 1974 of 113,000 porpoises and our previous preliminary projection for 1974 of 132,000 to 161,000 porpoise deaths. It appears, however, that the estimated total mortality of porpoises will probably increase in 1975 over the level estimated for 1974.

The species composition data for observed killed and observed seriously injured porpoises compiled to date for the 1975 field-technician operations are shown in Table 13. The estimate of seriously injured porpoise is 4.9% of the kill estimate overall and is 5.1% for spotted dolphin and 6.6% for eastern spinner dolphin. It is possible that a large proportion of the observed seriously injured porpoises died some time after release or that their long-term survival rate was affected, but we cannot confirm this assertion at this time.

3.2 Estimation of Population Size

Smith (1975) presented an analysis of data obtained from the 1974 NMFS field-technician operations and an aerial survey conducted in January-February 1974 to estimate the size of populations of the offshore spotted dolphins and the eastern spinner dolphins. Previous estimates of population sizes (Perrin, Smith, and Sakagawa, 1974) were based on a

preliminary analysis of the aerial survey, where data from the 1974 aerial survey were used to estimate the density of schools of porpoise but estimates of school size were obtained from the 1973 field-technician program. Examination of data from the 1974 field-technician program, however, revealed that the average number of spinner dolphins in mixed schools was considerably higher in 1974 than in 1973. The preliminary estimates were also based on the assumption that the density of porpoise schools observed in the aerial survey was representative of their density throughout their range. This assumption was also examined in Smith (1975). We believe that the present estimates, therefore, are much improved over those reported previously (Perrin, Smith and Sakagawa, 1974; Royce, 1974).

The population estimates are also based on the assumptions that all porpoise are seen in schools directly under the airplane or on a fishing vessel's path, estimates of school size are not significantly biased, and the geographical ranges of the populations are known. Work scheduled for calendar year 1976 is designed to examine the last assumption. A number of other technical assumptions are necessary, and were examined and discussed by Smith (1975).

3.2.1 Aerial survey estimates of school densities

In late January and early February 1974 an aerial survey was conducted off the coast of Central America to provide observations on the number of porpoise schools sighted along preset track lines. A Grumman Goose aircraft, specifically modified for aerial surveys, was

used. The aircraft was flown at altitudes between 1,000 and 1,500 feet, depending on cloud cover, and within 500 miles of the coast (Figure 7). The total distance covered by the survey was 11,538 miles. Line transect theory (Seber, 1973) was used to estimate numbers of porpoise schools per square mile from the observations.

The estimated density of schools was 0.95 per 1000 square nautical miles for pure spotted dolphins, 0.16 per 1000 square nautical miles for pure spinner dolphins, and 1.37 per 1000 square nautical miles for mixed schools consisting of spotted and spinner dolphins (Smith,1975).

3.2.2 Ship survey estimates of school densities

In 1974 field technicians were instructed to record observations on porpoise schools and information on searching effort; useable information was obtained from only 25 of 36 trips within the CYRA. As was done for the aerial survey, the line transect method was used for the ship surveys to estimate densities of porpoise schools. A total distance of 73,008 miles was searched. Since it was thought that school densities and sizes may be dependent on time and area, the estimates were stratified by early (January and February) and late (March to June) seasons and by nine sub-areas (combinations of North, Central, and South, and nearshore, middle, and far offshore), and were also examined in the aggregate. School densities tended to be highest in the early season and in the central-nearshore sub-area. Using all data, the average density for pure schools of spotted dolphins was 1.45 per 1000 square nautical

miles, for pure spinner dolphin schools it was 0.27 per 1000 square nautical miles, and for mixed schools it was 1.03 per 1000 square nautical miles. Overall porpoise school densities in the early season (January-February) tended to be about one and a half to twice those found in the late season (March-June). A major portion of the difference was attributed to the fact that the fishing vessels concentrated their effort on porpoise fishing in the early season, which tended to elevate the estimates, and non-porpoise fishing in the late season, which tended to depress the estimates. Densities in individual time-area strata varied about six-fold, but sample sizes were quite small in some time-area strata.

3.2.3 Estimates of population size

Offshore spotted dolphins were estimated to inhabit 2.6 million square nautical miles and eastern spinner dolphins 1.2 million square nautical miles (Figure 7). From the ship surveys the 1974 average school size was 518 for spotted dolphins and 762 for spinner dolphins. School size for a given species appeared to be independent of whether or not the school was pure or mixed. School size tended to be largest in the nearshore-central area and was slightly higher in the early season than in the late season. Sample sizes, however, were very small in some time-area strata.

Porpoise-school density estimates from the aerial and ship surveys were made in the aggregate. The ship survey density estimates were also made by stratifying by season and sub-area and computing an average, weighted by the geographical area of each stratum. Additional

estimates of density were made which combined the aerial and ship survey. Assuming that the ship survey estimates of density tend to be biased, either due to concentrated fishing for yellowfin tuna associated with porpoise or alternately fishing for yellowfin tuna and other species not associated with porpoise, a correction factor was obtained by the ratio of the aerial survey density to the ship survey density in the period and area of overlap. This ratio was applied to the full range of the ship survey, which is more extensive in areal coverage than the aerial survey. This combined approach additionally assumes that the aerial survey density estimates are accurate and the degree of bias in the ship survey is constant throughout its range.

The aerial and ship survey density estimates, along with the geographical ranges and average school sizes resulted in the following total ranges in estimated population sizes:

Stock	Estimated total range of population size (millions of animals)
Offshore spotted dolphin	2.8-4.2
Eastern spinner dolphin	1.0-1.5

The lowest values of the total ranges result from using the early-season density averages of the combined aerial and ship surveys. The highest values of the total ranges result from using the early-season density averages of the ship survey alone.

The estimated total ranges in population size can be centralized further, because certain of the density estimates are preferred over others. The ship survey is preferred over the aerial survey because of its broader areal coverage. The all-season density averages are preferred over the early-season density averages because of the biases discussed above. The sub-area density averages are preferred over the aggregate density averages because of apparent differences in density among sub-areas. Combining these preferences results in the following centralized ranges in estimated population sizes:

Stock	Estimated centralized range of population size (millions of animals)
Offshore spotted dolphin	3.1-3.5
Eastern spinner dolphin	1.1-1.2

The lowest values of the ranges result from the combined aerial and ship surveys and the highest result from the ship survey alone. We have no basis to choose between them.

It is important to note that the above estimated population size ranges are ranges of point estimates rather than probabilistic confidence intervals. Even though approximate variances were computed for the density and school size estimates and their combination, it is meaningless to try to place a probabilistic confidence interval on the current estimates, because neither the geographical range of each stock is known precisely nor do we have an estimate of its variance. More extensive aerial surveys, ship surveys independent of fishing, or alternate methods will have to be mounted to establish single point estimates with probabilistic confidence bounds.

We note that the above population size estimates are approximately the same for offshore spotted dolphin as the preliminary estimates previously reported in Perrin, Smith, and Sakagawa (1974) and Royce (1974). However, the above eastern spinner dolphin estimates of population size are nearly twice the previously reported preliminary estimates. We consider those of the present report to be much improved over the preliminary estimates because of our examination of the two critical assumptions.

3.3 Current Status of Offshore Spotted Dolphin

In the previous sections we provided estimates of the incidental mortality due to fishing operations and population sizes for the offshore spotted dolphins. In this section we review estimates of the biological parameters and bring the information together to provide our current understanding of the status of the offshore spotted dolphins..

3.3.1 Biological parameters of spotted offshore dolphins

Perrin, Coe, and Zweifel (MS) reported on an extensive study of growth and reproduction of the offshore spotted dolphins. Their paper has been submitted for publication and is available from the Southwest Fisheries Center upon request to the Center Director. The abstract of their paper follows:

"This study is based on data from several thousand specimens of spotted porpoise incidentally killed in the purse seine fishery for yellowfin tuna, *Thunnus albacares*. Average length at birth is 82.5 cm.

Gestation is 11.5 months. Average length at 1 year is 138 cm. Length-weight equations are given for fetuses and postnatal males and females. Age was estimated from dentinal layers in thin sections of teeth. A two-phase Laird-Gompertz growth model was fitted to the layer-length data. Direct calibration of the dentinal layers beyond the first year (two layers) was not possible, and three alternative hypotheses were considered: 1) two layers per year, until pulp cavity occluded, 2) two layers per year in first year, and one per year thereafter, and 3) two layers per year until puberty, and one per year thereafter. The second alternative is most probably the correct one, but reproductive parameters were estimated in terms of layers. Breeding is diffusely seasonal, with prolonged calving seasons in spring and fall and a pronounced low in winter. A third calving season may exist in the summer. Average age at attainment of sexual maturity of males is approximately 12 layers (average length about 195 cm and average weight about 75 kg). Females attain sexual maturity on the average at about 9 layers and 181 cm. Ovarian changes in adult females are described. Apparently post-reproductive females were encountered in the samples. It is concluded that corpora albicantia of ovulation and pregnancy persist indefinitely in the ovaries. It was not possible to distinguish between the two types of corpora. Ovulation rate changes with age, from about four per layer in very young adult females, to about one per layer in older females. The average reproductive cycle lasts 26 months and consists of 11.5 months of pregnancy, 11.2 months of lactation, and 3.3 months of "resting" (not pregnant or lactating). About 10% of lactating females are also pregnant. Pregnancy rate decreases with age, from about 0.6 per year at 8 to 10

layers, to about 0.3 at 16 layers. The overall sample contained 44.9% males and 55.1% females. Sex ratio changes with age, from near parity at birth, indicating higher mortality rates for males. Gross annual production of calves, based on age and sex structures of the sample and the estimated pregnancy rate, is 14.4% of the population per year. No evidence was found of age or sex segregation in schooling. The estimated parameters differ in a consistent way from those estimated for a population of *Stenella attenuata* in the western Pacific, possibly reflecting the exploitation in the eastern Pacific."

3.3.2 Current status of the stock of offshore spotted dolphins

Three annual rates are critical to assessing the status of stocks: the rate of production of calves, the rate of natural mortality, and the rate of incidental fishing mortality. For any given stock these rates may or may not be age-specific and may or may not be density-dependent. At equilibrium and prior to exploitation the production of calves would be balanced by natural mortality. We have no information to determine if the offshore spotted dolphin population was in equilibrium prior to exploitation by the tuna fishery. It is often noted that the reproductive rates of populations increase as the population is depressed, either through exploitation or natural causes. The natural mortality rate may also decrease, but in practice this rate is much more difficult to estimate than the reproductive rate. The effect of changes in these rates allows a sustained level of incidental fishing mortality with the population achieving a new equilibrium at some level lower than the

original. We examine these mechanisms with two models (one simple and one age-specific) which incorporate our current estimates of reproductive, natural mortality and incidental fishing mortality rates.

Perrin, Coe, and Zweifel (MS) estimated that the rate of gross annual production of calves is about 14.4% of the offshore spotted dolphin population in the eastern Pacific. This estimate is predicated upon their assumption that the samples are representative of the actual population. Perrin, Holts, and Miller (1975) estimated the gross annual production rate of calves for spotted dolphin of the western Pacific to be about 8.7% from data presented by Kasuya et al. (1974). The western Pacific population is thought to be very lightly exploited and may be in equilibrium; the adult female annual natural mortality rate was estimated to be 7.4% (Kasuya et al., 1974), but juvenile and male mortality rates are probably higher, so the population's average natural mortality rate is probably near the gross annual production rate of calves. Perrin, Coe, and Zweifel (MS) suggest that the higher reproductive rate in the eastern Pacific population might be a population response to exploitation because the individual reproductive parameters differ between the two populations in a manner consistent with that hypothesis. The higher reproductive rate may also be due, in part, to the culling of less productive adult animals, usually older individuals of the population. If the hypothesis is true, then the reproductive rate of the western Pacific spotted dolphin, 8.7%, is an estimate of the natural mortality rate, and carrying out the analogy with a simple model indicates that the present eastern Pacific population might sustain an annual incidental

fishing mortality rate of 4.4%[4/] or more, if the natural mortality rate were concomitantly depressed.

Perrin, Coe, and Zweifel (MS) point out that the reproductive rates tend to be age specific as is the case for natural mortality rates in mammals for which it can be reliably estimated. Perrin, Smith, and Sakagawa (1974) reported on an age-specific model. In this more complex approach, however, the aging assumptions are critical. By trying several aging assumptions and by using imputed age-specific natural mortality rates from the reproductive rates of a different population, that of the western Pacific spotted dolphin population (Kasuya et al., 1974), under the assumption that the population was in equilibrium, Perrin, Smith, and Sakagawa (1974) obtained a range of -2.5% to +6.6% for a sustainable annual incidental fishing mortality for the offshore spotted dolphins of the eastern Pacific. They argued further that the most probable range is +1.4% to 4.0%.

The total mortality of offshore spotted dolphins in the eastern Pacific during 1974 was estimated to be 72,000 animals (Table 10). The central estimates of population size were 3.1 to 3.5 million animals, with a total range of 2.8 to 4.2 million animals, giving a central range for the 1974 incidental fishing mortality rate of 2.1% to 2.3% and a total range of 1.7% to 2.6%. The estimates of the incidental fishing mortality rate are below that indicated as sustainable in the simple model, 4.4%, indicating that the population would increase but at a slow

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[4/] The calculation for competing rates is ((1 + 0.144) x (1 - 0.087)-1) x 100.

rate of 1.7%[5/] per year or slightly more. The estimates of the incidental fishing mortality rate are within the probable range of that indicated as sustainable in the age-specific model, indicating that if the population were changing it would be doing so at a very low rate (i.e., between decreasing at 1.2% and increasing at 2.2% per year).

With our present information we tentatively conclude that if the offshore spotted population were changing under the 1974 level of incidental fishing mortality, it is probably doing so at a low rate. Our tentative conclusion is unaltered even if we double our estimated incidental mortality rates of 1974, as some people have suggested, to account for certain possible but largely unknown effects, such as disruption of normal behavior, serious injuries (those observed were only 5% of the observed total kill in 1975), presumed higher foreign kill rates (the estimated foreign catch of yellowfin tuna associated with porpoise was 12% in 1974), or presumed higher kill rates on regulated trips to the west of the CYRA.

It is too early in 1975 to make a precise estimate of total incidental mortality of offshore spotted dolphin, but using our best estimate of 93,000 to 214,000 total porpoises killed (Section 3.1.3) and the present species composition of 60.4% spotted dolphin (Table 13), the 1975 mortality of offshore spotted dolphin is likely to be in the range of 56,000 to 129,000 animals. This is 22% lower to 79% higher than the incidental fishing mortality estimate for 1974 and would not alter our

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[5/] The calculation for competing rates is ((1 + 0.044) x (1 - 0.026) - 1) x 100.

tentative conclusion of a low rate of change in population size, 1973-1975.

Because of the low rates of change that we estimate with our present information, we believe it necessary to closely monitor and sample the population over at least the next 3 to 5 years, to reasonably determine the actual trend in the population. Some precision will be gained in our present understandings, however, if a breakthrough is obtained in our attempts to: directly calibrate tooth layers with actual age, determine porpoise searching effort in earlier years, and utilize other methods such as tagging on a large scale or a complete aerial survey.

3.4 Current Status of Eastern Spinner Dolphins

In this section we review the preliminary estimates of the biological parameters of the eastern spinner dolphins and bring together our estimates of incidental fishing mortality and population size to assess the current status of the stock. As yet, no attempts have been made to formulate an age-specific population model because the biological studies are currently in progress and the relevant parameters were estimated just prior to compiling this report.

3.4.1 Biological parameters of eastern spinner dolphins

Perrin, Holts, and Miller (1975) reported on preliminary results of a planned extensive study of growth and reproduction of the eastern spinner dolphins. While the results are preliminary, they are

based on large samples and we do not expect that major changes in the estimates of the parameters will occur in the final version of their study. The authors estimated that:

1) Average length at birth is 75.7 cm.

2) Gestation is 10.5 months.

3) Average length of males at attainment of sexual maturity is 170 cm. Average length of adult males is 175.5 cm (range 160 to 192 cm).

4) Average length of females at attainment of sexual maturity is 167 cm. Average length of adult females is 170.6 cm (range 153 to 187 cm).

5) Approximately 1% of adult females are post-productive.

6) Estimates of annual pregnancy rate range from 0.266 (based on 1973 data) to 0.4371 (based on 1974 data). The pooled estimates for all years data is 0.358.

7) The overall sex ratio is 1.02 males:1 female. The ratio changes from 1.22:1 at birth to 0.95:1 in adult-sized animals.

8) Estimates of gross annual reproductive rate based on 1973 and 1974 data are 6.4% and 9.8%, respectively. The estimate based on pooled data for the 2 years is 8.3%.

3.4.2 Current status of the stock of eastern spinner dolphins

In Section 3.4.1 the gross annual reproductive rate was estimated to be 6.4% for 1973 and 9.8% for 1974, with a pooled estimate of 8.3%. This is considerably below the rate estimated for offshore spotted dolphins in the eastern Pacific, suggesting that the stock of the eastern spinner dolphins cannot bear as much total mortality as the stock of spotted dolphins. However, depending on the natural mortality rate, it might sustain a higher or lower incidental fishing mortality rate than that of the offshore spotted dolphin. The relatively high rate of reproduction exhibited by the spotted dolphin may be due to response to exploitation, as suggested by Perrin, Coe and Zweifel (MS) and Perrin, Holts and Miller (1975), differential culling of less productive animals, or a combination of the two. It is possible that spinner dolphins have been less heavily exploited than spotted dolphins in the past (i.e., prior to 1971); comparisons of several biological parameters with other cetaceans support this contention (Perrin, Holts, and Miller, 1975). Also consistent with recent heavier exploitation is the increase in gross annual production between 1973 and 1974 from 6.4% to 9.8%. If this change is due solely to increased reproductive capacity, then a minimal estimate of the available annual sustainable incidental fishing mortality rate is 2.8%[6/], the difference between the gross annuall production rates of 1973 and 1974. But an additional year's data is needed to support the possibility of a sustained increase in

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[6/] The calculation for competing rates is ((1 + 0.098) x (1 - 0.064) - 1) x 100.

reproduction rate. Analysis of the 1975 life history data should contribute to resolution of this question.

In 1974 the estimated central range of population size point estimates of eastern spinner dolphins was 1.1 to 1.2 million animals, with a total range of 1.0 to 1.5 million animals. The kill of eastern spinner dolphins in 1974 was estimated to be 21,000 animals (Table 10). Thus the estimated central range of the annual rate of mortality caused by fishing was 1.8% to 1.9%, with a total range of 1.4% to 2.1%, which is not appreciably different from that of offshore spotted dolphins. Since all these rates of fishing mortality are below our only estimate of that which is sustainable (2.8%), this indicates that the population would tend to increase at a very low rate at the 1974 level of incidental fishing mortality, but we have little confidence in concluding with our present information that the eastern spinner dolphin population is actually increasing. As for the offshore spotted dolphins, where the individual rates of change are also small, we tentatively conclude that if the eastern spinner dolphin population is changing, either increasing or decreasing, it is doing so at a low rate.

Using our best estimate of the range of incidental fishing mortality for 1975 (Section 3.1.3) and the present species composition of 19.4% eastern spinner dolphins, the 1975 mortality is likely to be in the range of 18,000 to 41,000 animals. This does not alter our tentative conclusion of a low rate of change in population size, 1973-1975.

We also believe it necessary to closely monitor and sample the population of eastern spinner dolphins over the next 3 to 5 years in order to reasonably determine the actual trend in the population. More important than for the offshore spotted dolphins, however, is the need to monitor the annual reproductive rate of the eastern spinner dolphins to determine whether the increase observed between 1973 and 1974 is sustained.

MORTALITY REDUCTION TECHNOLOGY

A principal objective of the Porpoise/Tuna Interaction program is to develop practical technology (methods and equipment) for reducing porpoise mortality that is incidental to purse-seine fishing for yellowfin tuna. Our task in doing so is put in perspective by the fact that about 95% of the porpoise encircled by the purse seine are released through the backing down procedure developed by the tuna industry (see Section 4.2 of the present report and Appendix A of DOC, 1974) and, in 1975, an estimated 2% were killed (Table 2). The remaining animals escape from the net by jumping over the corkline, or are rescued.

The 1975 field technicians estimated the physical causes of mortality by species in several broad categories (Table 14). The major physical causes of mortality are entrapment and entanglement. The data suggest that spinner dolphins are more prone to entanglement in net meshes and are more prone to be killed during "sacking up" operations (see footnote 2 of Table 14) than are spotted dolphins. Our statistics for the first 20 field technician trips of 1975 (Table 3) also reveal that more than 50 porpoise were killed in 51 of 624 sets (8%) resulting in a kill of 6,189 animals out of a total kill of 10,509 animals (59%). This continues the general conclusion of previous years that a small fraction of the sets result in a high fraction of the mortality (Table 3).

In 1975, it is apparent that net-collapse sets[7/], while infrequent in total porpoise sets, were still associated with a disproportionately

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7/ The corkline comes together, which can keep porpoise from surfacing for air or greatly increase the probability of entanglement.

high rate of incidental porpoise mortality. Net collapses occurred in 57 of 624 porpoise sets (9%) with a corresponding kill of 3,032 of 10,509 animals (29%). Of the high-kill sets (those in which more than 50 porpoise were killed), net collapses occurred in 17 of 51 sets (33%) with a corresponding kill of 2,503 of 6,189 animals (40%).

In the remainder of this section we examine further the causes of mortality and describe our approaches to reducing incidental porpoise mortality.

4.1 Use of Speedboats to Prevent Net Collapse

Prior gear research efforts on several charter cruises resulted in the development of a system of using speedboats to hold the net open to prevent net collapse prior to backing down. In our system, three speedboats are used to hold the net open in the approximate shape of a large pentagon (Figure 8) giving considerably more surface area for containment of fish and porpoise than is normally available after pursing is completed and prior to backing down. On two gear charters in 1973 and 1974 our speedboat system was used, when needed, to prevent net collapse. Of 45 sets observed, speedboats were needed nine times and used experimentally two other times when not needed. None of these observed sets had net collapses even though conditions, such as strong currents and malfunctions that caused long delays, that often result in net collapses occurred during several sets.

We are convinced that use of speedboats, when needed, to hold the net open prior to beginning the backing down procedure would prevent net collapses and thus would reduce mortality. Also we believe that the larger surface area provided for fish and porpoise by use of speedboats will further reduce mortality through (1) minimizing the probability of porpoises coming in direct contact with the net, (2) preventing pockets of loose webbing, and (3) preventing many canopies of webbing under which porpoise become entrapped.

Some fishermen have expressed concern that the use of speedboats will result in significant loss of manpower from other required duties (e.g., stacking the net as it is hauled in). However, tests of the system during commercial fishing operations indicated that manpower loss to other operations was minimal. In most cases, only two speedboats were required to adequately hold the net open, and since one of these was the cork tender that normally stays in the water until after backdown, only one man was absent during the beginning of stacking the net. Whenever three speedboat drivers were used, the third driver was absent from stacking the net only during early hauling of the first one-quarter of the net. The second speedboat driver, whose speedboat was normally hooked onto bunchlines near midnet, also became available on the net pile before mid-net was reached. Because the greatest need for manpower in stacking the net is during hauling of the latter half of the net, these minor losses of manpower should be of little consequence.

4.2 The Porpoise Apron Device to Improve the Backdown Procedures

The backdown procedure, an efficient method of safely removing most porpoise from the net, was developed by the fishermen and is now used in virtually every set containing porpoise (Figure 9). Last year's progress report (DOC, 1974) summarized a description of the procedure from a paper by Coe and Sousa (1972) as follows:

"When approximately two-thirds of the net has been brought aboard, the hauling end of the net is secured and the vessel moves in a reverse direction through a wide arc aided by the seine skiff secured by a towing bridle . . . . During backdown, porpoise congregate at the extreme end of the net while the tuna tend to swim back and forth between the porpoise and the seiner. When the tuna are near the seiner, the vessel is backed rapidly to cause the corkline to submerge at the end of the net where the porpoise are located. As backing down proceeds, the corkline is pulled under the porpoise to release them unharmed.

"When the tuna swim towards the backdown area, and threaten to escape from the net, the boat is slowed and the corks rise to the surface. Usually, several such operations are necessary to back out the porpoise. Generally the procedure is aided by a crewman in a small skiff (the net tender) stationed at the end of the channel, who signals the captain when the fish are away from the release area and helps the porpoise over the corkline. When necessary he attempts to pull the corkline to the surface to retain fish."

A new modification of existing purse-seine gear designed to improve the backing down procedure, the "porpoise apron" was tested during a gear charter cruise in October and November 1974. The porpoise apron is a trapezoidal-shaped strip of webbing added to the net in the vicinity of the existing porpoise safety panel (Medina panel), which is now required on every vessel, Figure 10. The principal functions of the porpoise apron are to prevent formation of canopies of webbing during backdown that sometimes entrap porpoise, and to reduce the depth of pocket at the end of the backdown channel (Figure 9), which will allow faster and more effective releases of porpoise.

Use of the apron changes the normal operational procedure prior to and during backdown. The principal changes are:

(1) depression of the corkline by the weight of porpoise rather than vessel speed,

(2) a smooth continuous backdown rather than repetitive "backdown-stop-backdown-stop," etc., procedure which results in a reduction of total backdown time,

(3) a requirement for pulling the same number of bunches in every set and precisely marking the tie-down points for the net and the last bunch line, and

(4) use of fish to force out the last few porpoise.

Results from gear charter cruises and commercial fishing operations have been encouraging. At the suggestion of representatives of the tuna industry, captains and owners of 10 vessels volunteered certain expenses and assumed the risk of trying out porpoise aprons during the 1975 season. All captains who have completed trips in which the apron was installed have been interviewed. Six of eight captains believe that the apron improved their ability to save porpoise. Six of eight captains also believed that the apron made backing down easier. Seven of eight captains believed that time was required to learn proper use of the apron. All of the captains intend to continue to use the apron.

In the following paragraphs we attempt to quantitatively analyze the performance of the apron. Field technicians were placed on two vessels carrying the apron during the first half of 1975. Data from only one of these trips has been processed at the time of writing (the apron was not installed until the fourth set). In our gear charter cruise which tested the apron, the first 8 and last 10 sets used for studies of other experimental gear were discarded from the analysis. The results from the two trips are similar. The porpoise sets were categorized by school type, number of porpoise captured, and yellowfin caught as in our analysis of fleet performance (Tables 4 and 5). Kill per apron set was lower than the fleet average (Table 15) for all categories but one, sets on mixed schools that captured more than 500 porpoise and more than 20 tons of yellowfin tuna. We also calculated the standard error of the mean for kill per apron set (Table 15). The mean kill per

apron set plus or minus two standard errors overlapped with the mean fleet kill per set for three comparisons indicating that the differences are not statistically significant. On the other hand, it appears that apron sets on mixed schools in which less than 20 tons of yellowfin are caught could be significantly lower than the fleet average.

We also compared the number of porpoise remaining in the net after backdown, for sets that did not experience a net collapse prior to backdown, during the 1975 field-technician apron trip with the average of the remaining 1975 field technician trips. The fleet average was 15.76 animals remaining in the net after backdown, while the apron trip had only 10.11 animals remaining in the net after backdown. While these results are encouraging, we must note that reports from other field technicians aboard vessels trying out the apron and from the captains who have used aprons indicate that the apron is not an automatic success. These reports indicate that the apron has not always been properly centered in the backdown area or the necessary changes in procedures have not always been made, at least for the first part of a trip, and consequently the apron has not always worked as designed.

While we are encouraged by the early results of tests of the apron, we believe that more developmental work must be done. We believe that some design modifications may improve the basic dynamics of the apron and an opportunity to experiment with alternate configurations in the fleet would be beneficial. Reports of the difficulties in learning how to use the apron effectively indicate that an educational package on

the use of the apron would be helpful. During the remainder of this year we will conduct further tests on the apron and modified versions, and will prepare an educational package on the use of the apron.

4.3 Use of Fine Mesh Webbing to Prevent Mortality Due to Entanglement

The Medina panel was developed by Captain Harold Medina, who in 1971 replaced the 4-1/4 inch mesh in the backdown area of his net with a 720-foot long, 36-foot-deep strip of 2-inch-mesh webbing to reduce the chances of porpoise becoming entangled in the mesh during the backdown maneuver (Figure 9). In that year the "Medina panel," as it came to be called by the fishermen, was also tested by Captain Joseph Medina, Jr. These experienced and skilled skippers concluded that the smaller mesh netting was effective in reducing porpoise mortality, and by the end of the 1972 fishing season, similar panels had been installed in nets of approximately 40-50% of the U.S. tuna seiners. Further voluntary adoption raised the percentage of U.S. nets equipped with such a panel to about 60-70% of the fleet by the end of 1973. Statistical studies revealed that the Medina panel reduced mortality in troublefree sets by about 35% (NOAA, 1972) or more (Fabrick and Faverty, 1974).

Although the Medina safety panel is now required in every net, entanglement is still a major cause of porpoise mortality (Table 14). Field technicians were asked to note the locations of entanglement in their logbooks during 1975, but because there was not a specific place

on their forms for the location of entanglement, the field technicians often failed to do so. However, field technicians on 14 of 19 trips that captured porpoise in 1975 noted that some porpoise were entangled in 2-inch mesh; more than 370 porpoise were recorded as being entangled in the 2-inch mesh during 93 sets. Porpoise were also recorded as being entangled in 4-1/4-inch mesh below the Medina panel. Another cause of entanglement is that after backdown is completed the portion of the net containing the Medina panel is often brought aboard the vessel leaving only 4-1/4-inch mesh webbing in the water. Studies at the SWFC show that significant entanglement can occur until mesh size approaches 1 inch (Figure 11). With these facts in mind 1-1/4-inch mesh webbing was used for the original porpoise apron. Experimental work will be conducted during the remainder of the calendar year using a 1-1/4-inch mesh Medina panel and additional areas of fine mesh webbing designed to reduce entanglement.

4.4 Large Volume Purse Seine

The preceding subsections discuss minor modifications of existing gear and techniques to reduce porpoise mortality. We have also designed a new purse seine which is described in last year's progress report (DOC, 1974). The new net provides a larger volume of water than the standard purse seine, which can safely contain large catches of fish and porpoise. The porpoise safety panel has a smaller mesh (1-1/2 inch) than usual mesh (2 inch), and the net is tapered to reduce canopies and pockets of loose webbing.

Tests of the new net on the fishing grounds under charter and on a voluntary basis resulted in a very low porpoise kill for 65 sets in which 1,179 tons of tuna were caught with 4.97 porpoise killed per set and 0.27 porpoise killed per ton of yellowfin tuna. In addition, the net was used for exploratory fishing in the central Pacific by a larger and newer seiner. Results, however, indicated that the net needed to be lengthened for the average new vessel and this was accomplished. The large volume and tapered net concepts worked well for at least two captains and two vessels. However, we believe that the design must receive further tests with different captains and different vessel types. We therefore, have an agreement with a vessel owner to try it on several vessels. The net is currently being tested on a fishing trip and an NMFS gear research technician is aboard the vessel to record the performance of the net.

4.5 Anti-Torque Purse Line to Prevent Roll-Ups

A roll-up is a common gear malfunction that occurs whenever the purse line contacts any part of the net and rotates sufficiently to wind the net around it producing a long, sausage-like configuration. Correcting this condition causes interruption of seining operations (DOC, 1974). During 1975, roll-ups that caused delays occurred in 33 of 624 sets. Any delay in a porpoise set places the porpoise in jeopardy for longer periods of time. In an attempt to solve the problem of roll-ups we tested an anti-torque purse line, which is a wire rope constructed with sub-cables twisted in opposite directions to the lay of their inner strands to reduce rotation under strain. Preliminary results of testing and evaluation during charter cruises on the fishing grounds were encouraging.

Several vessels, however, have used the anti-torque cable this year and found that while it does tend to reduce roll-up problems, the material used for the cable does not presently have sufficient durability to be used as standard equipment. Cable with better durability is available, but requires the use of purse blocks with larger diameter sheaves than are now standard. Further work is planned on this problem.

4.6 Use of Ribbons as Current Indicators

Subsurface currents that are often not apparent until trouble begins are an important cause of net collapse. A ribbon current indicator, consisting of a fluorescent colored ribbon with a float at one end and a 2-ounce weight attached to the other, has been developed and tested (DOC, 1974). The ribbon is wound around the float for storage and when cast in the water the weight rapidly reels the ribbon off the float. Near the surface the angle of departure from the vertical indicates magnitude of current, and the ribbon streaming away from the cork indicates direction. Preliminary experience was encouraging, but further tests indicated that for some situations both the length of the ribbon and the 2-ounce weight should both be doubled. This has been done and the ribbons are being tested on two fishing vessels at the time of writing.

4.7 The Porpoise Grabber, a Porpoise Rescue Device

After normal backdown and post backdown rescue procedures are completed, a few live porpoise frequently evade rescue attempts by

staying in the center of the net as it is rolled aboard and many are eventually killed during sacking up (Table 14). Some of these porpoise are usually removed during sacking up operations, in manners sometimes hazardous to both porpoise and fishermen.

In an attempt to improve rescue technology, primarily just prior to sacking up, we developed a long handled "porpoise grabber" device to assist rescuers in removal of all live porpoise (Figure 12). The grabber is a light-weight, long-handled pole fitted with spring-loaded stainless steel prongs contoured to fit the shape of the porpoise's body and hook behind the flippers without injury to the animal. The tip of each prong is covered with a ball; when in use the prongs spread apart over the animal's body and spring back into position behind the flippers. The porpoise grabber can be used to guide loose porpoise out of the net or reach deeper along the sides of the net to extract entangled animals that would be out of hand's reach.

Two versions of the "porpoise grabber" are currently undergoing tests aboard two tuna vessels operating in the eastern tropical Pacific. NMFS gear technicians are aboard the vessels to collect data on the performance of the device.

SUMMARY

The Porpoise/Tuna Interaction Program of the Oceanic Fisheries Resources Division, Southwest Fisheries Center was reviewed for Fiscal Year 1975 (July 1, 1974 through June 30, 1975). The current status of the 1975 field-technician operations was summarized. Progress of research and development efforts on: the U.S. tuna purse-seine fleet performance in reducing the incidental mortality rate under comparable conditions during 1973-1975, the status of the porpoise stocks affected by the incidental mortality, and technology for reducing the incidental mortality, was reported. Our tentative conclusions are:

(1) Total porpoise mortality from fishing in 1975 will probably be greater than in 1974. The revised preliminary kill estimate for 1974 is 113,000 animals (98,000 by U.S. vessels). The preliminary kill estimate for 1975 is 93,000 to 214,000 animals. Using the same percentage as in 1974 (87%), the U.S. kill for 1975 will probably be 81,000 to 186,000 animals. Among the identifiable causes for a higher total incidental mortality in 1975 are:

(a) there has been increased fishing for yellowfin tuna associated with porpoise;

(b) kill per set for mixed schools (spotted dolphin and spinner dolphin) is strikingly higher than that for pure schools of spotted dolphins. In 1975, there was a sharp, and at presesent inexplicable, increase in the number of mixed schools fished.

(2) Because of the prevalance of mixed schools, the observed aggregate kill per set in 1975 increased over 1974 (from 12 per set in 1974 to 17 per set in 1975. The latter figure, though large, is still far from the 43 per set observed as recently as 1972).

(3) Because the kill per set is correlated with the nature of the schools set upon (pure or mixed), and other factors such as catch of yellowfin tuna and number of porpoise captured, it is necessary to standardize the data before years can be directly compared. Such a standardization shows that under comparable conditions of catch, the kill per set actually decreased from 1974 to 1975. The decrease was 22%. It probably reflects better U.S. fleet performance, particularly increased use of rescuers at the corkline.

(4) Foreign involvement in catching yellowfin tuna associated with porpoise increased six times (2% to 12% of the total) from 1971 to 1974.

(5) Refined estimates put the stock of offshore spotted dolphins in the eastern Pacific at 3.1 to 3.5 million animals. The estimated incidental fishing mortality rate for 1974 is 2.1% to 2.3%. Our best estimate at present is that, biologically, the population could sustain an annual fishing mortality rate

of 1.4% to 4.4%. There is no striking evidence that the stock is either increasing or decreasing. At present the stock is probably stable or increasingly or decreasing slightly.

(6) Similar estimates place the stock of eastern spinner dolphins in the eastern Pacific at 1.1 to 1.2 million animals and the 1974 annual rate of mortality caused by fishing at 1.8% to 1.9%. Our best estimate at present is that, biologically, the population could sustain an annual incidental fishing mortality of 2.8%. As with the spotted dolphin, there is no striking evidence that the stock is either increasing or decreasing. At present the stock probably is either stable or increasing or decreasing slightly.

(7) Technological developments that are certain to further reduce incidental porpoise mortality are the use of speedboats, when needed, to hold the net open prior to the execution of backing down and the use of rescuers at the corkline.

(8) Technological developments that require further testing and analysis but that are promising to further reduce incidental porpoise mortality are: (a) certain design features of the large volume purse seine, (b) finer mesh Medina panels and use of fine mesh in other areas of the nets, (c) the porpoise apron, and (d) the porpoise grabber.

The analyses supporting several of our tentative conclusions still have a number of shortcomings, as noted in the respective sections of the present report. We have yet to analyze all of the factors associated with the kill per set (Section 2.2.5). Since we have examined the major factors of species composition, amount of yellowfin tuna captured, and number of porpoise captured, we believe that our examination of the additional factors will probably reduce variation and not alter our conclusion that the kill per set adjusted for comparable conditions decreased from 1974 to 1975.

Our estimates of porpoise mortality are for direct observable deaths only and do not include estimates of other direct or indirect deaths which may occur. Our present attempt to account for some of these possible additional deaths indicates that those seriously injured (Section 3.1.3) were minor compared with other difficulties in total mortality estimation. The major shortcomings are the lack of estimates of the kill per set for non-U.S. vessels and for U.S. vessels fishing west of the yellowfin tuna regulatory area (CYRA). We do not believe that these shortcomings seriously affect our conclusions that the total incidental mortality of porpoise will probably increase in 1975 over 1974 and that the major porpoise stocks in the eastern Pacific are either stable or increasing or decreasing slightly.

We still have the problem of direct calibration of tooth layers to age and the assumption that our biological sampling is representative of the porpoise populations. These shortcomings make our present estimates

of the reproductive parameters provisional. As pointed out in Section 3.3.2, however, the probable range in the reproductive parameters resulting from different aging assumptions does not alter our conclusion on the status of the offshore spotted dolphins. Our conclusion on the status of the eastern spinner dolphins is more provisional than that for offshore spotted dolphins, until work on the 1975 samples is completed.

The population estimates in the present report (Section 3.2.3) are better than the previously-reported, preliminary estimates because we have examined several critical assumptions and have examined both our aerial and ship surveys. Estimation of school size should receive more attention although all cross-checks currently possible (correlation with back-calculated observer estimates and comparison between ship and aerial survey estimates) reveal no major discrepancies. The boundaries of the offshore spotted dolphin should be better defined.

In previous reports (e.g., Royce, 1974) we examined back-calculated population sizes. Calculations of this nature are speculative and resulted in such wide bounds that we did not believe it useful to repeat them. The only reasonably useful data for examining previous population size may be the IATTC data base on number of porpoise sets and the amount of fishing effort expended. We expect to study the problem of definition of porpoise fishing effort during the present Fiscal Year (Sections 1.2.3 and 3.0) in order to examine the possibility of developing an index of porpoise abundance for previous years.

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FIGURES

Figure 1. The major part of the Inter-American Tropical Tuna Commission Yellowfin Regulatory Area (CYRA) and the principle zone of fishing outside the CYRA.

Figure 2. Frequency distributions of porpoise killed per all porpoise sets, 1971-1974, and for the first 20 field technician trips for 1975.

Figure 3. Average kill of porpoise per porpoise set by school type plotted against tons of yellowfin tuna and number of porpoise captured per set for 1975. Closed circles represent pure schools of spotted dolphins and open circles represent mixed schools consisting of spotted and spinner dolphins. Trend lines were fitted by inspection.

Figure 4. Average kill per set by school type and four groups of number of porpoise captured in the net and catch (tons) of yellowfin tuna, 1973-1975. Closed circles represent pure spotted dolphin schools and open circles represent mixed schools of spotted and spinner dolphins.

Figure 5. Average kill per set by school type and combined school types, 1973-1975. Closed circles represent observed values and open triangles represent values adjusted to comparable 1975 conditions of number of porpoise captured and tons of yellowfin tuna caught per set.

Figure 6. Average kill of porpoise per ton of yellowfin tuna from 1974 and 1975 field technician cruises plotted against cumulative porpoise sets observed. Open circle is a preliminary value including nine additional cruises for 1975, and the vertical line is the final value for the first 20 cruises of 1975 ±10 percent.

Figure 7. Location of track lines on the aerial survey in early 1974. Historical ranges for the offshore spotted dolphins and the eastern spinner dolphins, from Perrin (1975).

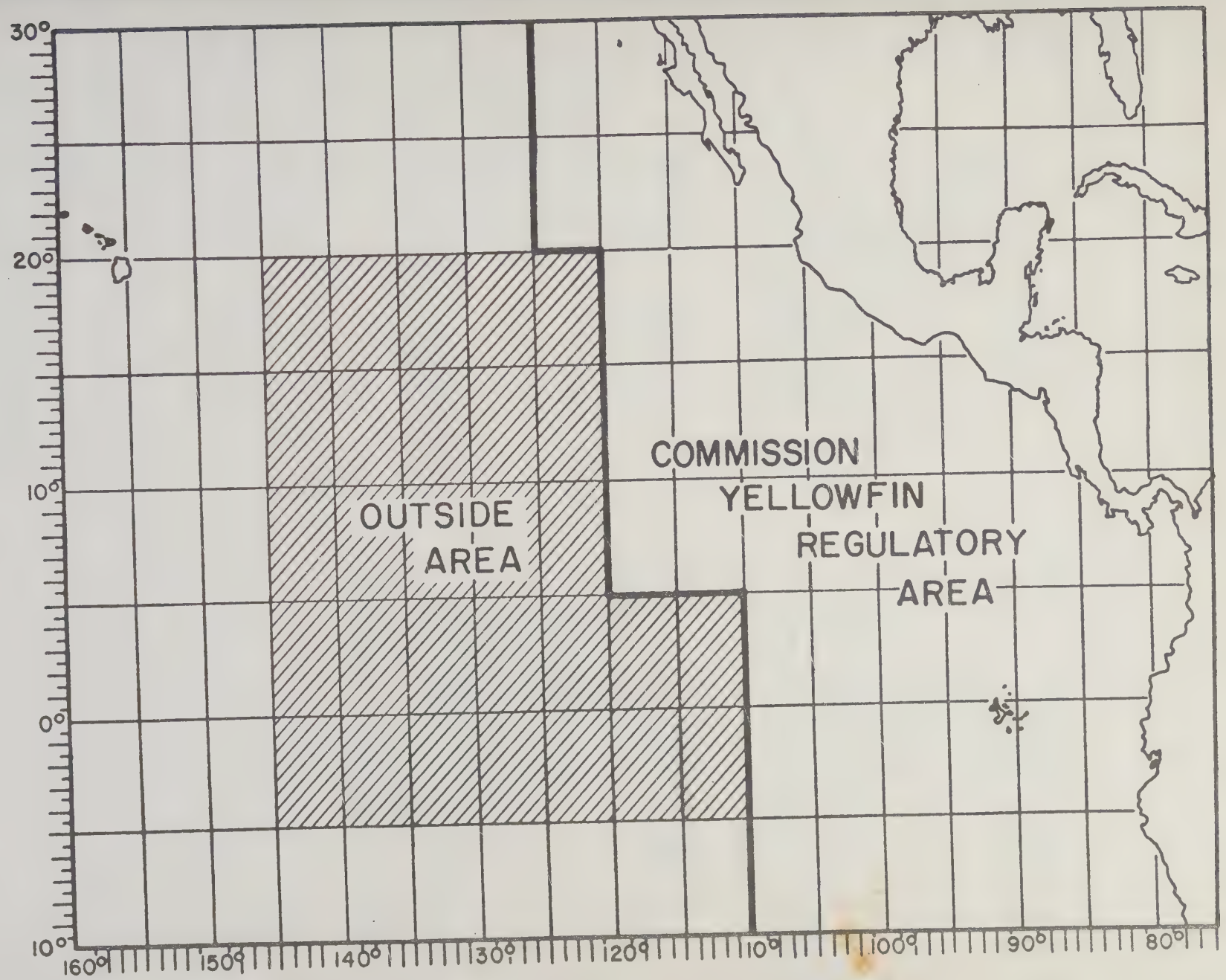
Figure 8. Idealized configuration of net under tow by speedboats.

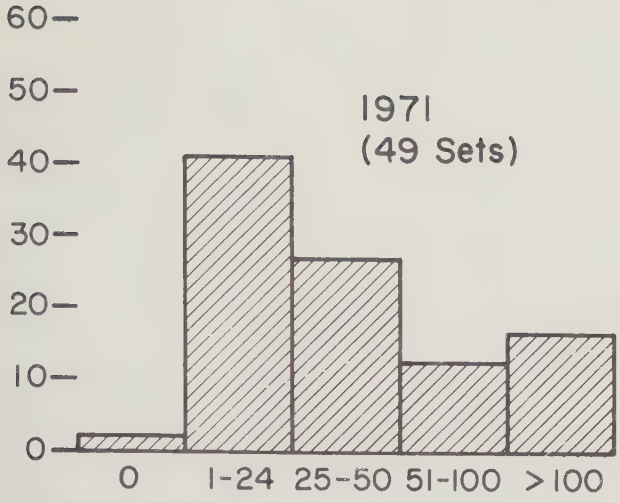
Figure 9. Backdown maneuver nearly completed and the net has narrowed into a finger-like channel. A number of porpoise are going over the sunken corkline near the net tender skiff and a number of freed animals can be seen. The bottom of the net close to the fishing vessel is visible and shallow, but deepens and disappears at the end of the backdown channel. (Official U.S. Navy photograph)

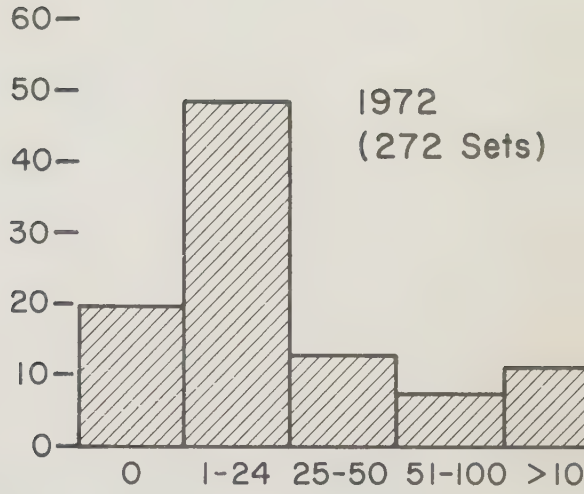
Figure 10. Schematic drawing of the configuration of the porpoise "apron."

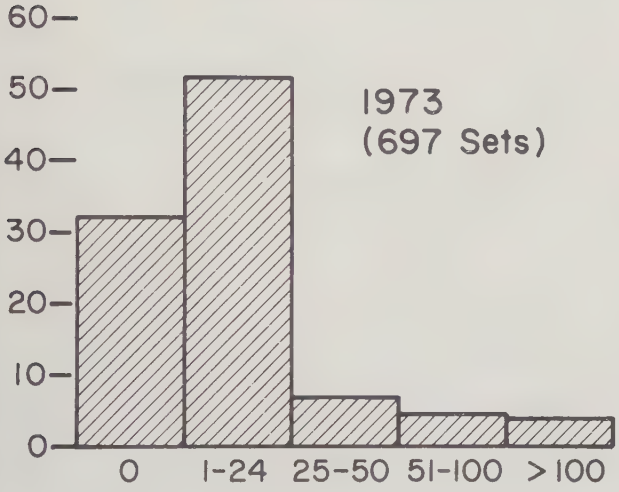
Figure 11. Experimental rate of entanglement relative to net mesh size.

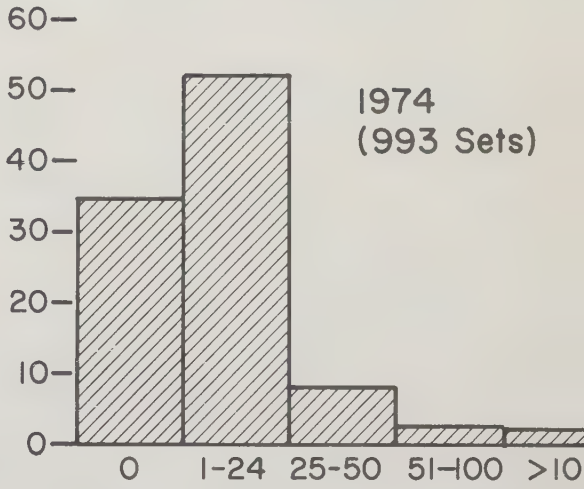
Figure 12. Prototypes of the porpoise "grabber," a device designed to aid in the safe manual removal of porpoise from the net.


30°
20°
10°
0°
10°
160°
150°
140°
130°
120°
110°
100°
90°
80°
OUTSIDE
AREA
COMMISSION
YELLOWFIN
REGULATORY
AREA



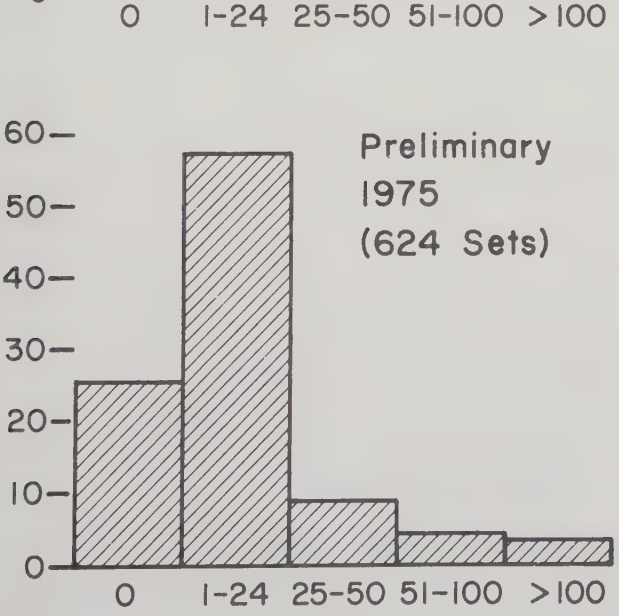




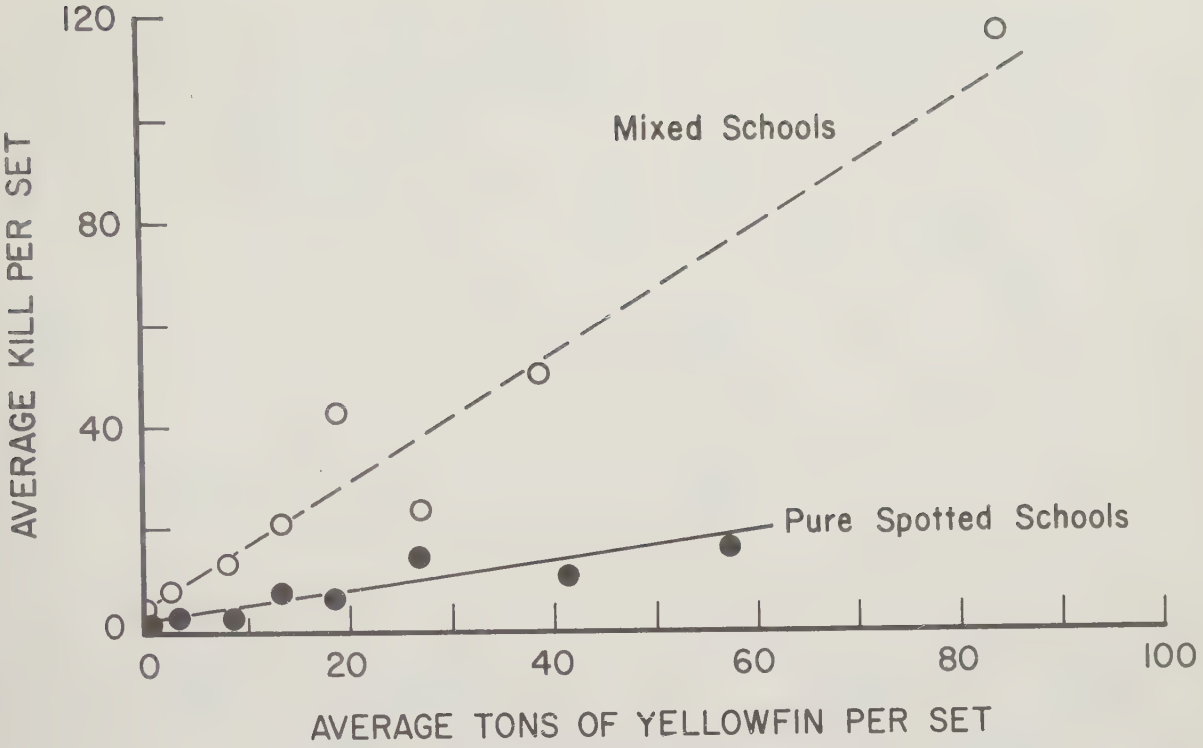


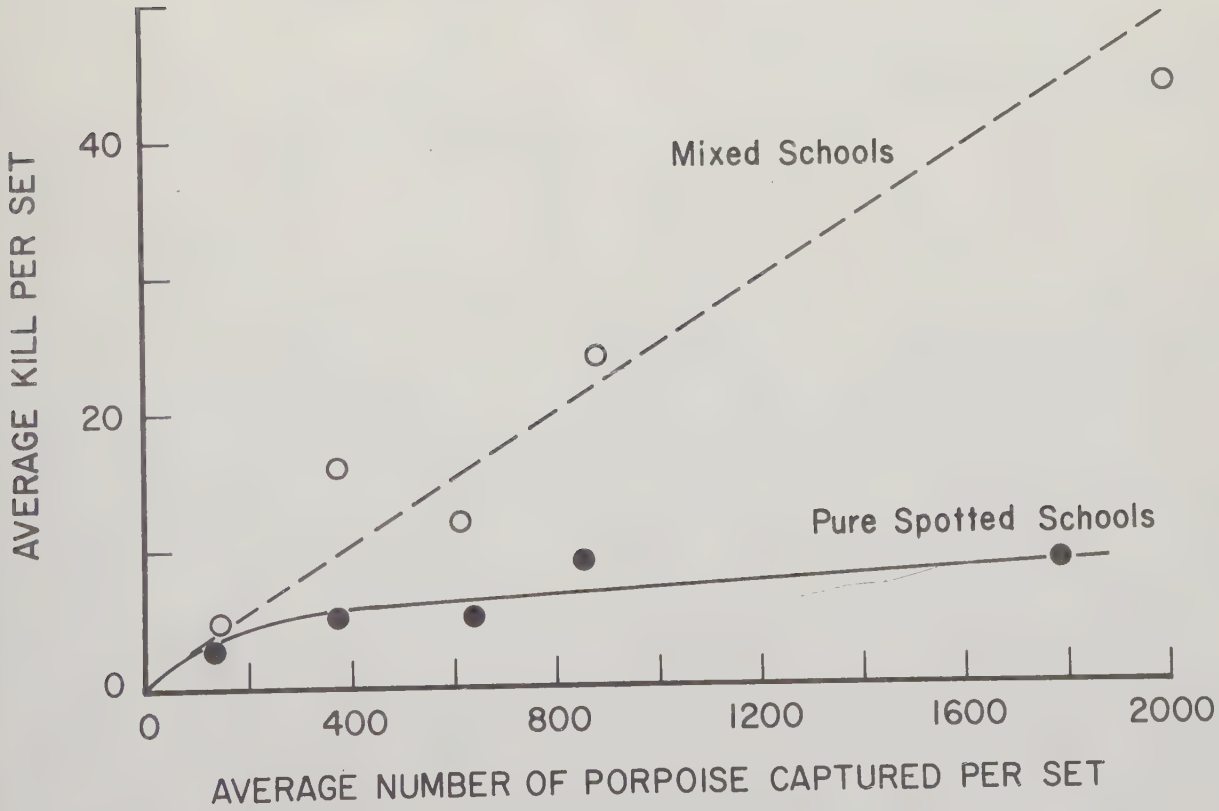
Percent of porpoise sets

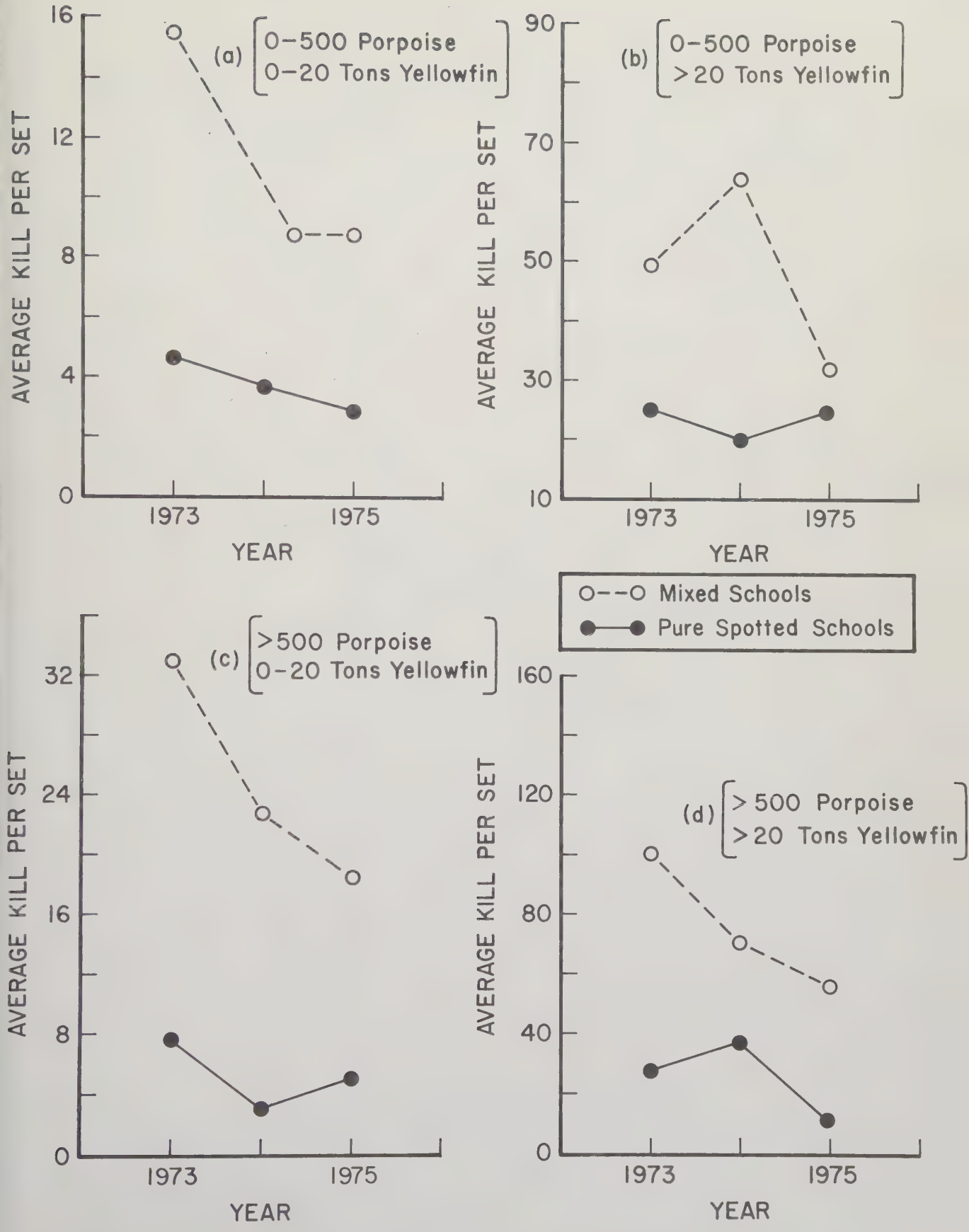
Porpoise killed per porpoise se

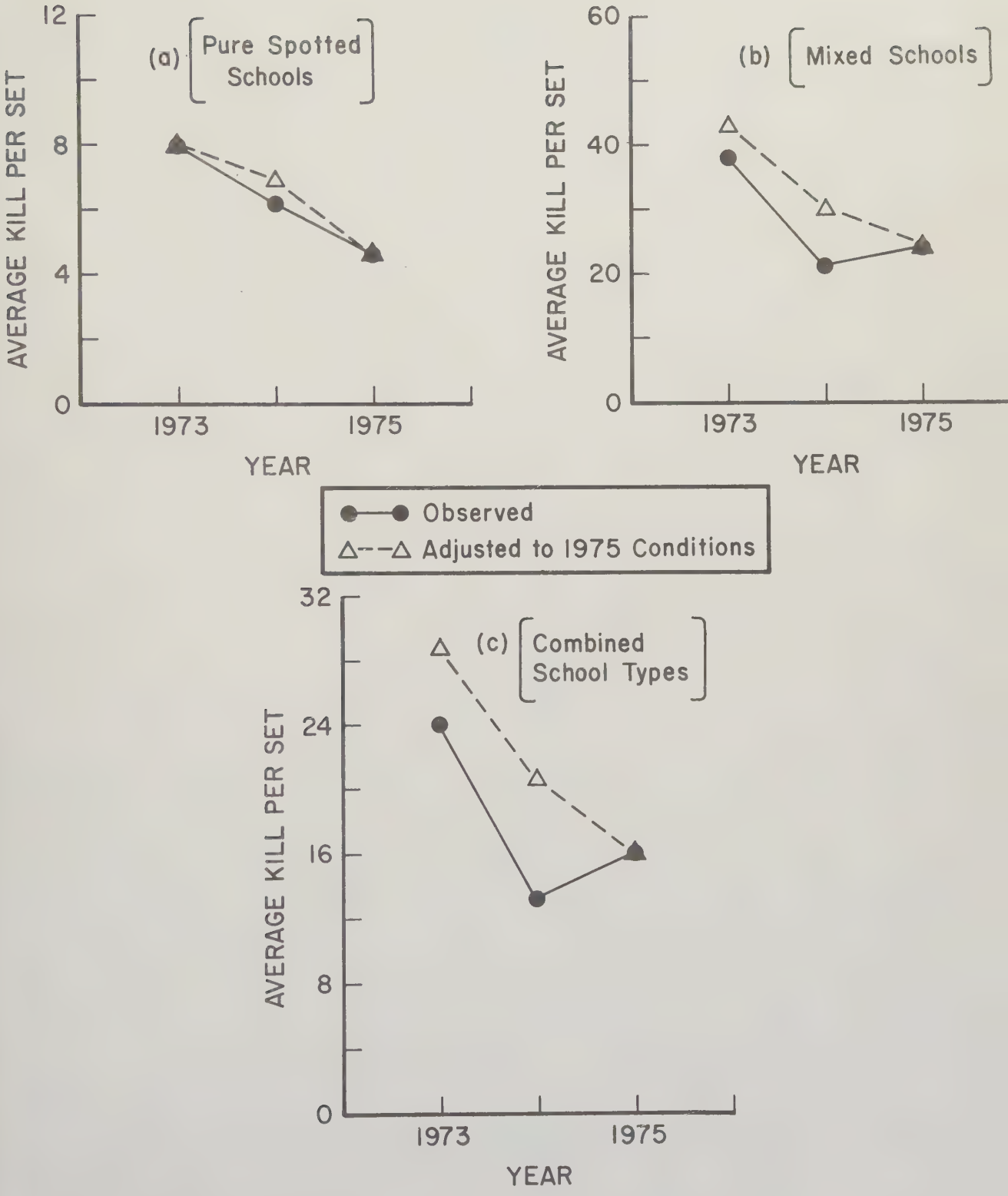


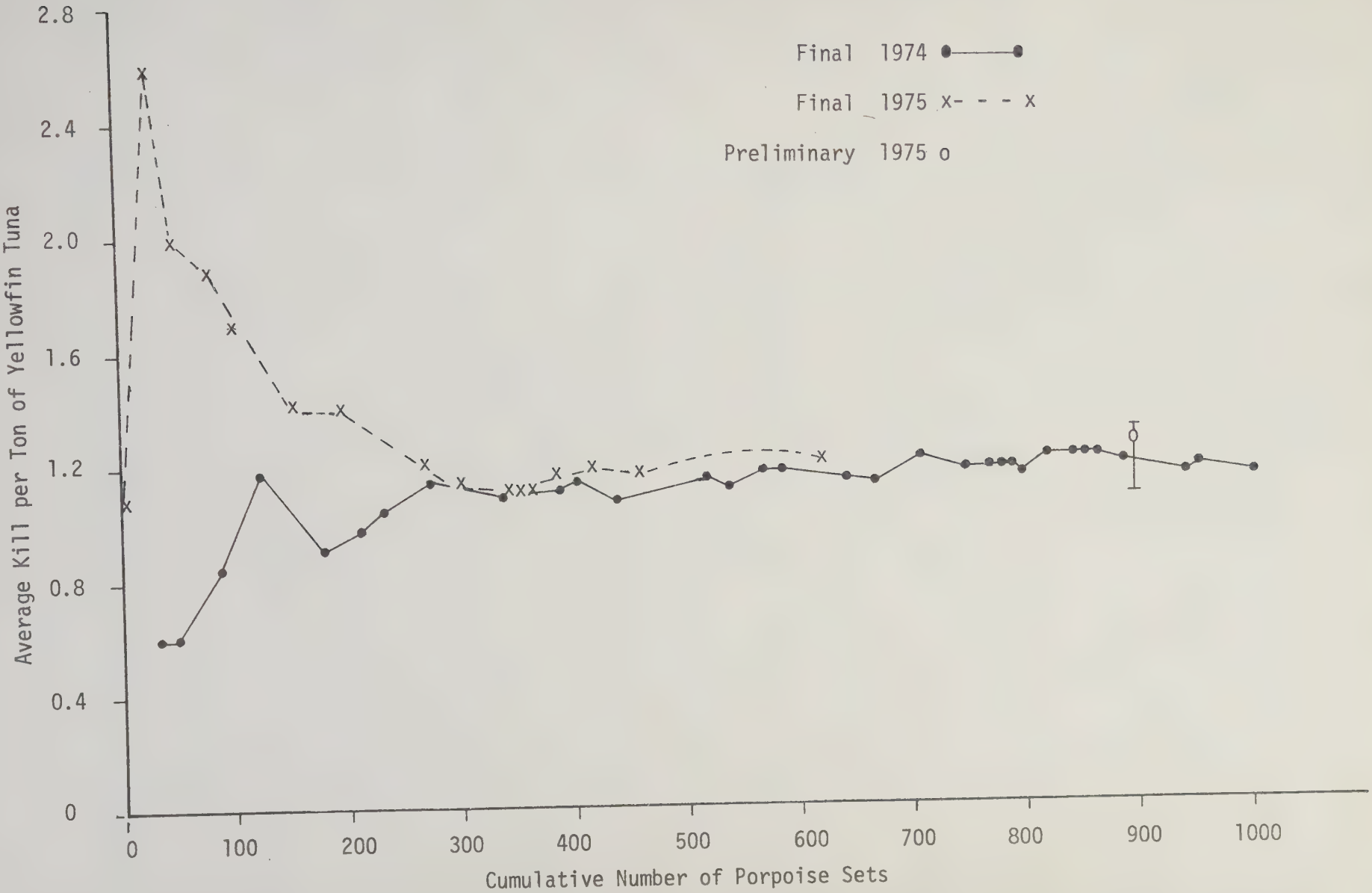
Porpoise killed per porpoise set

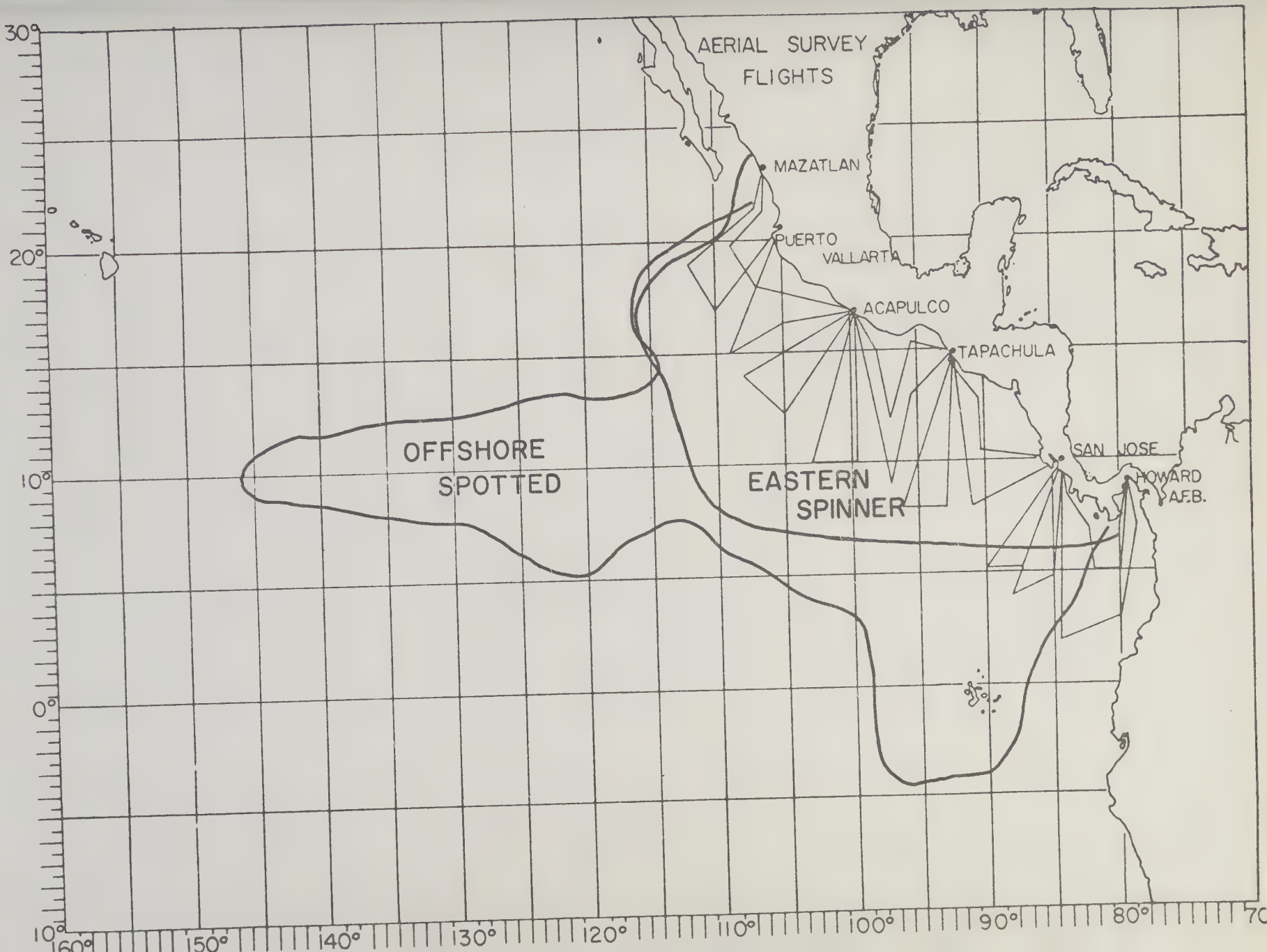

120
80
40
0
AVERAGE KILL PER SET
Mixed Schools
Pure Spotted Schools
0
20
40
60
80
100
AVERAGE TONS OF YELLOWFIN PER SET

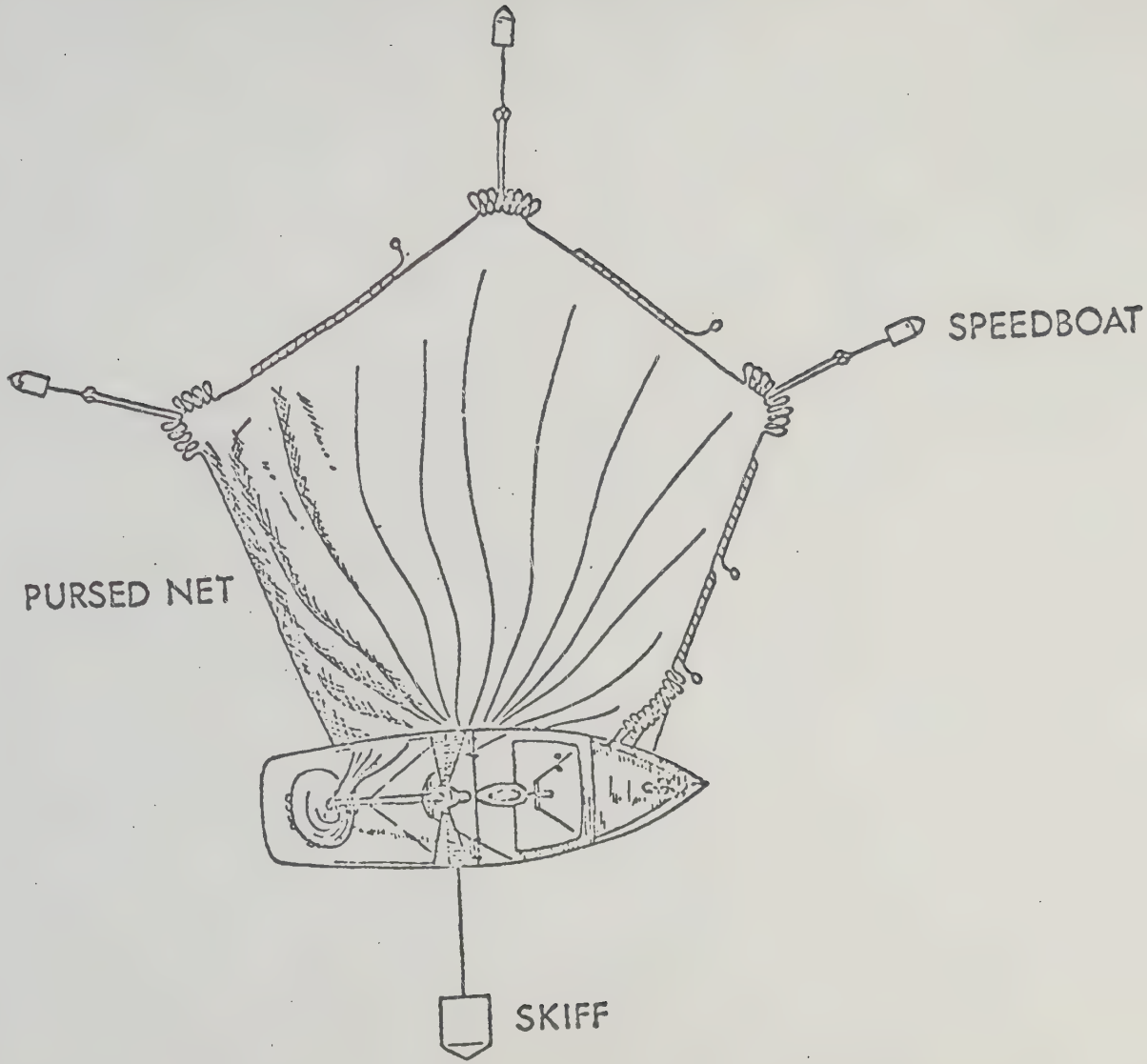

40
20
0
AVERAGE KILL PER SET
Mixed Schools
Pure Spotted Schools
0
400
800
1200
1600
2000
AVERAGE NUMBER OF PORPOISE CAPTURED PER SET

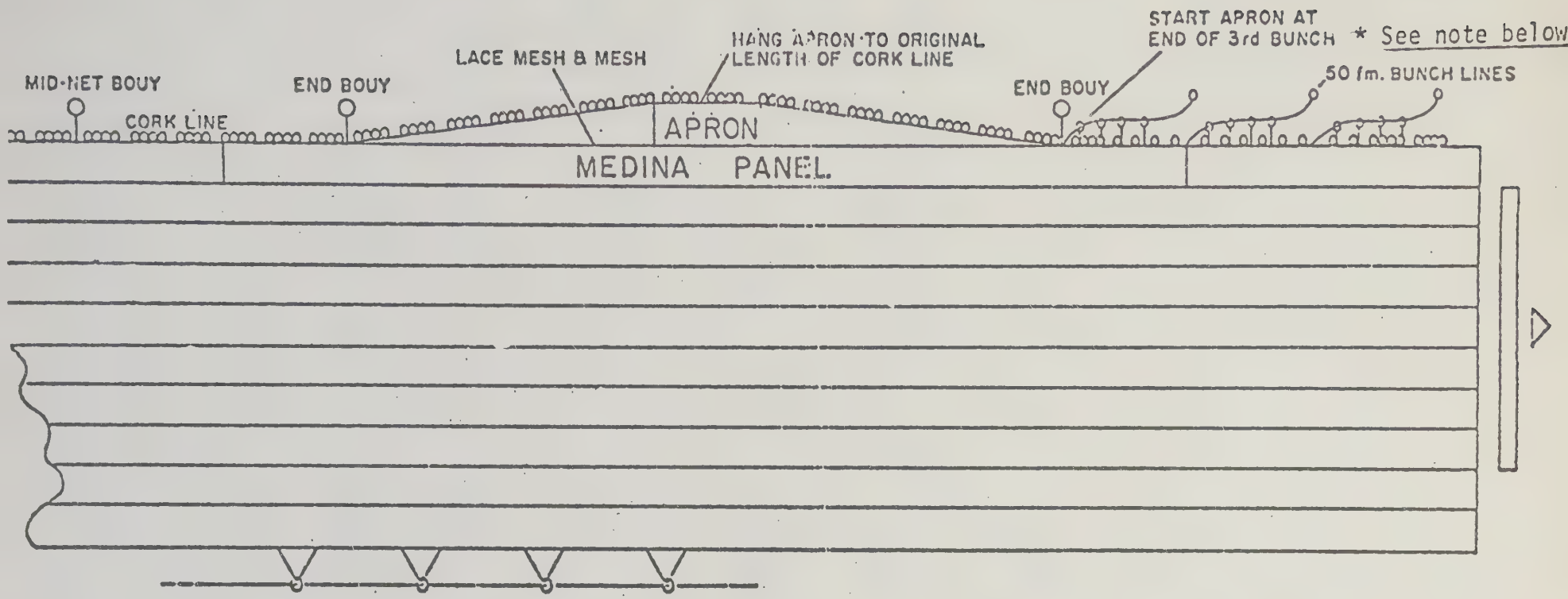

(a) 0–500 Porpoise
0–20 Tons Yellowfin
(b) 0–500 Porpoise
>20 Tons Yellowfin
(c) >500 Porpoise
0–20 Tons Yellowfin
(d) >500 Porpoise
>20 Tons Yellowfin
Mixed Schools
Pure Spotted Schools
AVERAGE KILL PER SET
YEAR
1973
1975
0
4
8
12
16
10
30
50
70
90
24
32
40
80
120
160


(a) Pure Spotted Schools
(b) Mixed Schools
(c) Combined School Types
AVERAGE KILL PER SET
YEAR
1973
1975
0
4
8
12
20
40
60
16
24
32
Observed
Adjusted to 1975 Conditions

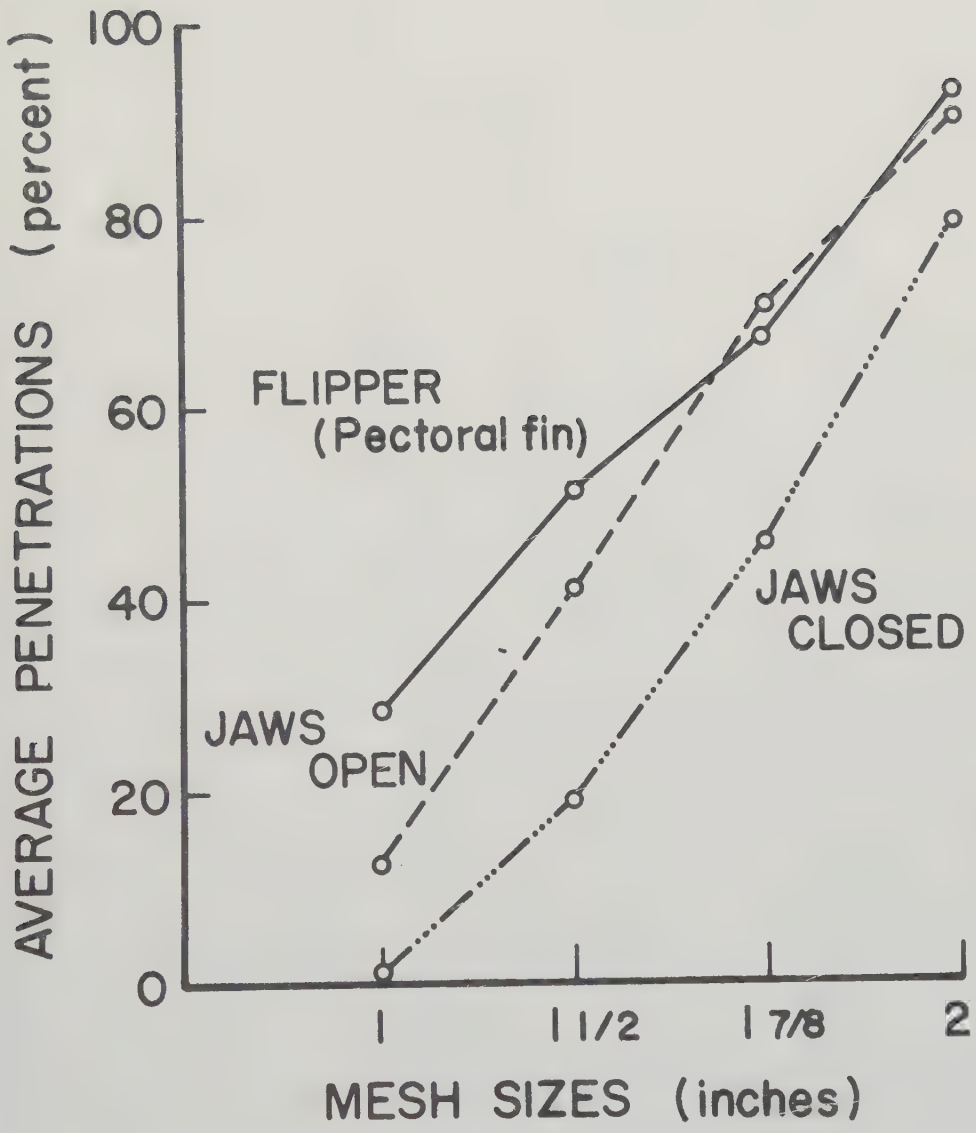

Final 1974
Final 1975
Preliminary 1975
Average Kill per Ton of Yellowfin Tuna
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
0
100
200
300
400
500
600
700
800
900
1000
Cumulative Number of Porpoise Sets


AERIAL SURVEY
FLIGHTS
MAZATLAN
PUERTO
VALLARTA
ACAPULCO
TAPACHULA
SAN JOSE
HOWARD
A.F.B.
OFFSHORE
SPOTTED
EASTERN
SPINNER
30°
20°
10°
0°
10°
160°
150°
140°
130°
120°
110°
100°
90°
80°
70


SPEEDBOAT
PURSED NET
SKIFF



* Start at end of third bunch for 10-strip nets ONLY! for 11-strip nets 5 fathoms beyond end of 3rd bunch. For 12-strip nets start 10 fathoms beyond. For 13-strip nets start 15 fathoms etc. etc..


AVERAGE PENETRATIONS (percent)
100
80
60
40
20
0
FLIPPER
(Pectoral fin)
JAWS
OPEN
JAWS
CLOSED
1
1 1/2
1 7/8
2
MESH SIZES (inches)

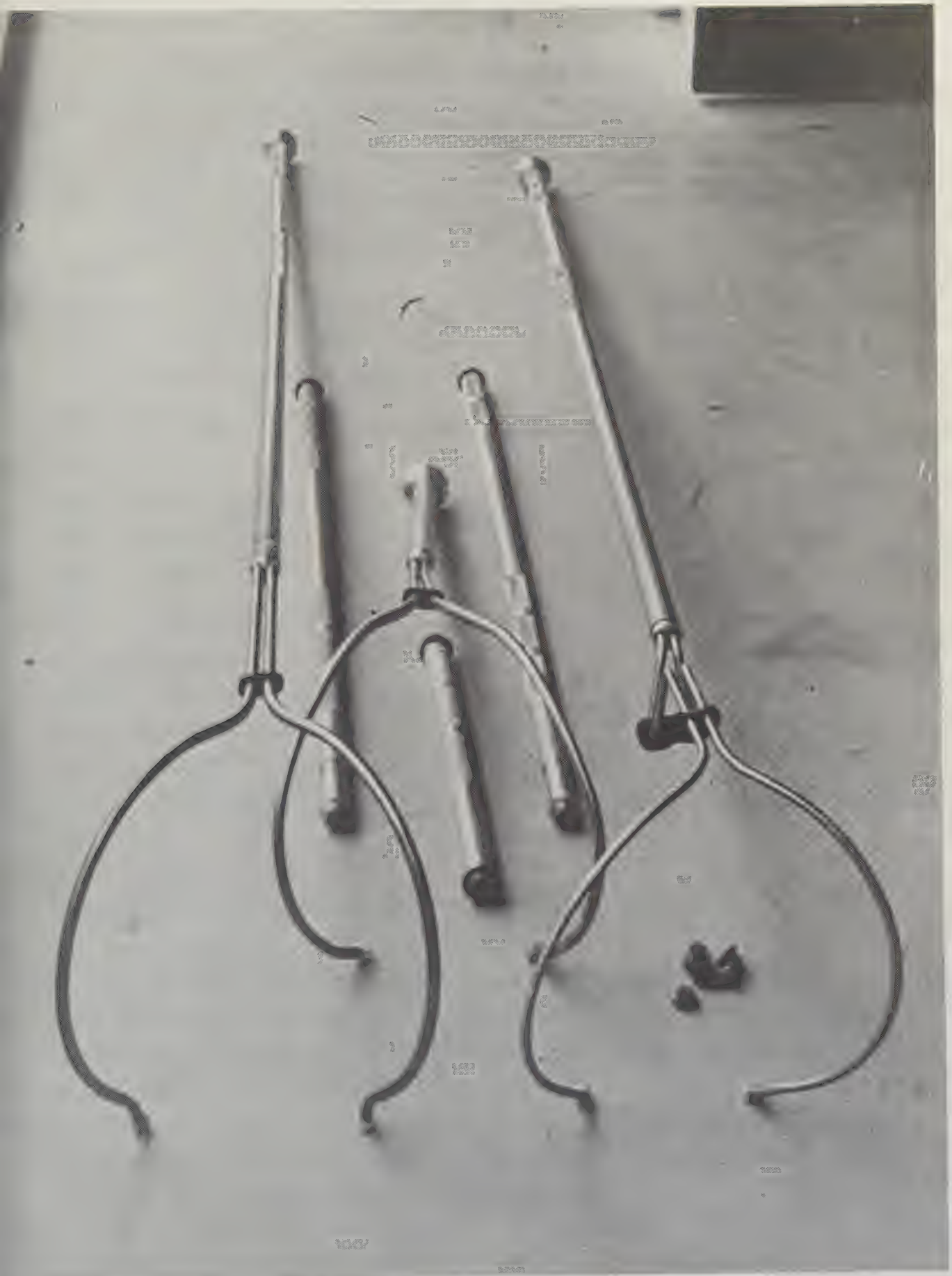


Table 1. Estimated eastern tropical Pacific tuna catch (1000's short tons)[1/], by country, species, and gear type, 1971-1974

	Year			
	1971	1972	1973	1974
U.S.[2/ 3/]				
Yellowfin tuna associated with porpoise	79	132	121	99
Total yellowfin tuna by purse seine	107	160	168	165
Total yellowfin tuna by all gear	110	163	176	170
Total tuna, all species	195	187	207	224
Non-U.S.[3/]				
Yellowfin tuna associated with porpoise	2	15	18	14
Total yellowfin tuna by purse seine	19	27	42	54
Total yellowfin tuna by all gear	27	34	54	61
Total tuna, all species	57	47	72	94
Total, all countries[3/]				
Yellowfin tuna associated with porpoise	81	147	139	113
Total yellowfin tuna by purse seine	126	187	210	219
Total yellowfin tuna by all gear	137	197	230	231
Total tuna, all species	252	234	279	318

[1/] Estimated from Inter-American Tropical Tuna Commission (IATTC) statistics

[2/] All U.S. domestic tuna landings (all areas and all species) for the years 1971-74 are 237, 263, 257, and 276 thousand short tons, respectively. (Source: U.S. Dept. Comm., 1975. Fisheries Statistics of the United States, 1974. CFS No. 6700, 98 p.)

[3/] Assuming all yellowfin tuna caught west of the IATTC Yellowfin Regulatory Area is by purse seine and by U.S. flag vessels.

Summary statistics of porpoise sets from NMFS field technician trips, 1971-1975. Numbers in parentheses are sample sizes

Statistic	1971	1972	1973	1974	1975[1/]
(1) Total number of porpoise sets	51	273	705	993	633
(2) Number of pure spotted dolphin sets	23	117	302	425	233
(3) Number of pure spinner dolphin sets	0	0	17	15	5
(4) Number of mixed spotted and spinner sets	25	132	279	365	342
(5) Number of common dolphin sets	2	23	105	142	10
(6) Number of others and unknown porpoise sets	1	1	2	46	43
(7) Average tons of yellowfin per set	18(48)	20(272)	14(705)	11(993)	14(624)
(8) Average number of porpoise caught per set	219(48)	49(245)	378(705)	355(980)	766(625)
(9) Average porpoise school size per set[2/]	298(48)	1007(239)	907(703)	1163(866)	1392(604)
(10) Average porpoise kill per set	70(48)	43(272)	19(705)	12(993)	17(624)
(11) Average porpoise kill per ton of yellowfin	3.8	2.2	1.3	1.1	1.2
(12) Percent porpoise kill per porpoise caught	31.9	8.9	4.9	3.4	2.2
(13) Percent of school captured[2/]	73.5	48.3	41.7	30.5	55.0
(14) Percent of school killed[2/]	23.5	4.3	2.1	1.0	1.2
(15) Percent of sets catching yellowfin	92(48)	89(273)	82(705)	74(993)	86(624)
(16) Percent of sets catching porpoise	100(48)	91(273)	86(705)	83(993)	95(624)
(17) Percent of sets catching porpoise with zero killed	2(48)	12(248)	18(601)	22(827)	22(594)

[1/] First 20 field technician trips.

[2/] Estimates generally have a low precision.

Table 3. Frequency distribution of porpoise kill per set for all porpoise sets, 1971-1975

Kill/ set interval	1971				1972				1973				1974				1975 [1/]			
	Sets		Kill		Sets		Kill		Sets		Kill		Sets		Kill		Sets		Kill	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
0	1	2.1	0	0.0	54	19.9	0	0.0	225	32.3	0	0.0	346	34.8	0	0.0	159	25.5	0	0.0
1-24	20	41.7	199	5.9	132	48.5	1064	9.1	362	51.9	2588	19.9	518	52.2	3416	28.3	358	57.4	2396	22.8
25-50	13	27.1	474	14.1	35	12.9	2131	18.2	48	6.9	1696	13.1	80	8.1	2843	23.6	56	9.0	1924	18.3
51-100	6	12.5	447	13.3	20	7.4	491	4.2	33	4.7	2340	18.0	27	2.7	1931	16.0	29	4.6	2026	19.3
>100	8	16.7	2237	66.6	31	11.4	8047	68.6	29	4.2	6353	49.0	22	2.2	3860	32.0	22	3.5	4163	39.6
Total	48	100.0	3357	100.0	272	100.0	11,733	100.0	697	100.0	12,977	100.0	993	100.0	12,050	100.0	624	100.0	10,509	100.0

[1/] First 20 field technician trips.

Table 4. Statistics from sets made on pure schools of spotted dolphins by class III vessels (1973-1975)

Number of porpoise captured	Catch of yellowfin				All sets	
	0-20 tons		Greater than 20 tons			
	Number of sets	Kill per set	Number of sets	Kill per set	Number of sets	Kill per set
1973						
0-500	118	4.64	19	14.89	137	6.07
Greater than 500	11	7.82	14	27.43	25	18.80
All sets	129	4.91	33	20.21	162	8.03
1974						
0-500	248	3.69	24	10.29	272	4.27
Greater than 500	23	3.00	19	37.11	42	18.43
All sets	271	3.63	43	22.14	314	6.17
1975						
0-500	155	2.86	11	14.82	166	3.66
Greater than 500	42	4.93	21	11.00	63	6.95
All sets	197	3.30	32	12.31	229	4.56

Table 5. Statistics from sets made on mixed schools of spotted and spinner dolphins by class III vessels (1973-1975)

Number of porpoise captured	Catch of yellowfin				All sets	
	0-20 tons		Greater than 20 tons			
	Number of sets	Kill per set	Number of sets	Kill per set	Number of sets	Kill per set
1973						
0-500	98	15.56	15	39.07	113	18.68
Greater than 500	31	33.68	38	100.42	69	70.43
All sets	129	19.91	53	83.06	182	38.30
1974						
0-500	164	8.83	12	53.58	176	11.88
Greater than 500	59	22.76	30	70.47	89	38.84
All sets	223	12.52	42	65.64	265	20.94
1975						
0-500	120	8.78	10	22.10	130	9.80
Greater than 500	128	18.41	79	56.29	207	32.86
All sets	248	13.75	89	52.45	337	23.97

Table 6. Statistics for sets made on pure schools of spotted dolphins and mixed sets of spotted and spinner dolphins, 1973-1975

Year	Pure spotted dolphin			Mixed spotted and spinner dolphin			All sets			
	Sets	Kill	Yellowfin catch (tons)	Sets	Kill	Yellowfin catch (tons)	Sets	Kill	Yellowfin catch (tons)	Kill/Set
1973	162	1301	2206	182	6971	3444	344	8272	5650	24.05
1974	314	1936	3537	265	5548	3280	579	7484	6817	12.93
1975	229	1045	2661	337	8077	5400	566	9122	8061	16.12

Table 7. Porpoise kill rates for 1974 field technician cruises that could be segregated by utilization rate of rescuers

Utilization rate	Number of vessels	Number of sets	Porpoise kill	Kill per set	Catch of yellowfin (tons)	Kill per ton of yellowfin
Always 2 or more	3	149	1066	7.15	2083	0.51
Sometimes 2 or more	3	87	818	9.40	896	0.91
Always 1	2	83	1054	12.70	1084	0.97
Seldom any	5	119	2071	17.40	1241	1.67
Total	13	438	5009	11.44	5304	0.94

Table 8. Proportion of live porpoise left in the net after backdown that were rescued prior to sacking uperations in 1975

Number of vessels	Number of sets	Number of live porpoise left in net after backdown	Number of live porpoise extracted by rescuers prior to sacking up operations	Proportion rescued
12	347	7932	3467	0.44

Table 9. Scope of status of stock analyses for the major species of porpoises involved in the eastern Pacific international yellowfin tuna purse seine fishery

Entity	Involvement in fishery[1]			Assessment status[2]			
				Exploitation rate		Capacity for increase	
	Major	Minor?	Negligible	Incidental mortality	Population size	Reproductive parameters	Natural mortality
1. Coastal spotted dolphin (*S. attenuata* subspecies)		X		A			
2. Offshore spotted dolphin (*S. attenuata* subspecies)	X			A	A	A	C
3. Costa Rican spinner dolphin (*S. longirostris* subspecies)			X	A			
4. Eastern spinner dolphin (*S. longirostris* subspecies)	X			A	A	B	B
5. Whitebelly spinner dolphin (*S. longirostris* subspecies)	X			A			
6. Common dolphin (*D. delphis*)	X			A			

[1] Major = more than 1000 killed incidentally per year
Minor = between 100 and 1000
Negligible = fewer than 100

[2] A = reasonable estimates, but subject to revision after further examination of critical assumptions.
B = preliminary estimates
C = estimates assumed from studies of other populations.

Table 10. Incidental porpoise mortality estimates (1000's of animals), 1971-1974, for U.S. and non-U.S. vessels

Year	U.S. Purse Seiners Within CYRA					Non-U.S. Purse Seiners Within CYRA					Outside CYRA					Total[1]				
	Spotted dolphin	Spinner dolphin		Common dolphin	Other	Spotted dolphin	Spinner dolphin		Common dolphin	Other	Spotted dolphin	Spinner dolphin		Common dolphin	Other	Spotted dolphin	Spinner dolphin		Common dolphin	Other	Total[1]
		Eastern	White-belly				Eastern	White-belly				Eastern	White-belly				Eastern	White-belly			
1971	129	91		4	Ø[2]	4	3		Ø	Ø	51	36		0	Ø	185	130		4	Ø	320
1972	174	41		8	Ø	30	7		1	Ø	69	16		0	Ø	273	65		9	1	347
1973	59	37		18	Ø	15	10		5	Ø	40	25		0	Ø	114	72		22	Ø	208
1974	40	16	4	3	Ø	10	4	1	1	Ø	23	2	10	0	Ø	72	21	15	4	Ø	113

[1] Differences between row totals caused by rounding

[2] Ø denotes fewer than 500.

Table 11. Number of actual trips[1/], and field technician data by three vessel and three trip classes for the 1974 yellowfin tuna unregulated fishing season

Vessel Class [2/]	Trip Category								
	Started and finished before closure			Started 1 week before closure and finished after closure			Started after 1 week before closure		
	Total trips	Sample		Total trips	Sample		Total trips	Sample	
		Trips	Average kill		Trips	Average kill		Trips	Average kill
I	19	3	250.0	10	0	-	18	0	-
II	15	1	906.0	5	1	102.0	13	0	-
III	67	15	452.9	13	1	563.0	57	8	70.1

[1/] Southwest Regional Office records.

[2/] Class I = Less than 401 tons carrying capacity
Class II = Greater than 400 tons carrying capacity and built before 1961
Class III = Greater than 400 tons carrying capacity and built after 1960.

Table 12. Number of actual trips[1/] and field technician data by two vessel and two trip classes for the 1974 yellowfin tuna unregulated fishing season

Vessel class [2/]	Trip Class					
	Early season [3/]			Late season [3/]		
	Total trips	Sample		Total trips	Sample	
		Trips	Average kill		Trips	Average kill
I	24	3	250.0	23	0	(37.9)[4/]
II + III	92	17	486.0	78	9	73.6

[1/] Southwest Regional Office records
[2/] See Table 11. footnote (2)
[3/] See text for explanation of season type.
[4/] 250.0 x (73.6/486.0)

Table 13. Preliminary 1975 species composition of the observed kill and seriously injured porpoise [1/]

Species	Killed	Seriously Injured [1/]
Spotted dolphin (*S. attenuata*)	6,495	332
Spinner dolphin (*S. longirostris*)		
Eastern	2,006	133
Whitebelly	1,755	34
Unidentified	145	12
All spinners	3,906	179
Common dolphin (*D. delphis*)	204	1
Others	143	14
Total Porpoise	10,748	526

[1/] Bleeding, with broken bones, or caught in power equipment

Table 14. Estimated physical causes of mortality incidental to purse seine fishing for yellowfin tuna in 1975.[1/] Numbers are in percent of total mortality of species

Cause	Spotted dolphin	Spinner dolphin	Others
Entanglement in meshes	36.2	39.1	24.6
Entrapment in net folds and canopies	42.6	35.5	66.0
"Sacked up"[2/]	15.8	20.2	5.5
Other	2.0	2.8	0.9
Unknown	3.4	2.5	3.0
Total	100.0	100.0	100.0

[1/] First 20 field technician trips.

[2/] Sacking up operations begin after backdown. The net is further rolled aboard making the volume of confinement for tuna and any remaining porpoise smaller to allow brailing of tuna into the vessel and manual removal of porpoises that could not be backed out.

Table 15. Comparison of average kill per set for all sets of 1975 field technician cruises aboard class III vessels and sets made with the porpoise apron--mean ± standard error of the mean (number of sets)

Sets on Pure Schools of Spotted Dolphins				
Average kill per set	0-20 tons of yellowfin per set		>20 tons of yellowfin per set	
	0-500 porpoise captured	>500 porpoise captured	0-500 porpoise captured	>500 porpoise captured
All sets	2.86	-	-	11.00
Apron sets	1.83±0.66(12)	-	-	5.75±2.95(4)
Sets on Mixed Schools of Spotted and Spinner Dolphins				
All sets	8.78	18.41	-	56.29
Apron sets	2.96±0.94(16)	4.10±1.22(10)	-	80.30±73.08(10)